

YIELD, YIELD COMPONENTS, AND NITROGEN ACCUMULATION IN  
GRAIN SORGHUM AS Affected BY MATURITY AND PLANT DENSITY

by

DAVID WILLIAM KOCH

B. S., Kansas State University, 1964

---

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1966

Approved by:

*Richard L. Vining*  
Major Professor

LD  
2668  
TY  
1966  
K76  
C.2  
Document

ii

TABLE OF CONTENTS

INTRODUCTION . . . . .	1
REVIEW OF LITERATURE . . . . .	2
Plant Density Effects on Yield . . . . .	2
Hybrid Effects on Yield . . . . .	4
Variations in Protein Level . . . . .	6
METHODS AND MATERIALS . . . . .	8
RESULTS AND DISCUSSION . . . . .	12
Stand Density and Hybrid Effects on Grain Yield . . . . .	12
Dry Matter . . . . .	36
Total Nitrogen . . . . .	37
Nitrogen Percentage . . . . .	47
SUMMARY AND CONCLUSIONS . . . . .	48
ACKNOWLEDGMENTS . . . . .	52
LITERATURE CITED . . . . .	53
APPENDIX . . . . .	56

## INTRODUCTION

Kansas ranks second among the states in grain sorghum production, surpassed only by Texas. Grain sorghum is second in acreage in Kansas, exceeded only by wheat. The yield per acre has doubled from 1940 to 1960. In excess of 90% of the crop is fed to livestock.

Grain sorghum is a popular crop in the Great Plains because of its adaptability, capacity to produce in adverse seasons, comparable nutritive value to corn, and increased yields through hybridization and improved cultural practices, particularly fertilization and irrigation.

Along with increased yields have come difficulties in maintaining high quality of grain. Notably, increased yields have a dilution effect on protein, the most important constituent of grain utilized by livestock. However, yield and protein level vary quite extensively with different cultural practices.

This study was intended to compare several plant densities and hybrids as they influence grain yields, components of yield, and protein levels. While extensive data are available concerning spacing and individual hybrid and variety effects on yield, little has been reported on the relationship of hybrid maturity to grain yield and protein content.

Nitrogen relations of the plant were an important aspect of these experiments. The nitrogen reserve in the plant before grain formation and the amount of nitrogen the plant was able to take up as the grain was developing were considered. The possibility of higher grain and nitrogen yields from late and medium compared to early maturing hybrids was investigated.

## REVIEW OF LITERATURE

## Plant Density Effects on Yield

Often plant spacing can vary considerably from the normal stand without materially affecting grain yields, as demonstrated by Nelson (25) and Robinson, et al. (33) in grain sorghum and by Kiesselbach, et al. (19) in corn. Leonard and Martin (22) state that grain yields can differ greatly from one year to the next, largely as a result of differences in rainfall.

The particular rate of planting varies from location to location, being determined mainly by soil moisture availability and soil fertility. Grimes and Musick (12) found 50 to 60 square inches per plant or slightly over 100,000 plants per acre to be optimum with irrigation in southwestern Kansas. Laude and Swanson (20) at Garden City, Kansas, reported dry-land grain sorghum in 40-inch rows with plants 12 inches apart in the row produced highest yields.

In general, highest yields were obtained from grain sorghum hybrids spaced six to eight inches in 40- to 44-inch rows (18,000 to 26,000 plants per acre) on semi-arid nonirrigated land in Texas (4, 18). Stickler, et al. (37) at Manhattan, Kansas, found a plant area of 60 to 80 square inches per plant to produce highest yields, except in 1955 when plant densities ranging from 60 to 160 square inches per plant in 10-, 20-, 30-, and 40-inch rows did not significantly differ. This was associated with lack of moisture during the season.

Increased populations are often necessary to fully utilize fertilizers or moisture, if other factors are not limiting (14, 26, 27). Heavier planting rates, however, with limiting moisture or soil fertility are often inferior to thinner planting. Kiesselbach, et al. (19) with corn suggested that planting rates be reduced whenever moisture is apt to be a limiting factor.

Stickler and Wearden (38) found only 10% reduction in yield by increasing area per plant from 60 to 480 square inches with 14 trials in eastern Kansas. There was a large variation of individual components, but a counterbalancing effect of increased number of seeds per head and decreased number of heads per unit area. The mean number of heads per plant varied from 0.87 to 4.50 for 60 and 480 square inches per plant, respectively.

Painter and Leamer (26) reported a significant spacing x fertility interaction. Increased yields were obtained with four-inch over nine-inch plant spacing in 36-inch rows only when 120 pounds or more of nitrogen was applied. Significant moisture x fertility and moisture x fertility x spacing interactions were also found, but no significant moisture x spacing interaction was shown. Greatest increases in yield with more frequent irrigations and closer spacings resulted only when nitrogen was applied.

Brown and Shrader (5) suggested that under severe drought conditions forage production should be kept at a minimum so that more water will be available for grain production. This can be accomplished by establishing more plants per row in wider spaced rows, thereby increasing plant competition, limiting forage growth, and increasing water use efficiency (bushels of grain produced by an acre-inch of water).

Comparable yields with thinner stands result mainly from the ability of sorghum plants to tiller and utilize space. The contribution of tillers to yield at wider spacings can be quite significant. Grimes and Musick (12) reported 2.30 and 2.78 heads per plant with 360 square inches per plant (33-inch rows and 12 inches between plants) in two years. No tillers were reported for plant areas below 50 to 60 square inches.

The number of tillers and tiller heads tend to be greater when plants are thinly spaced in the row, but the number of heads per acre is generally lower than in thick stands (20).

Tillering has been shown to be significantly reduced by increasing row width, keeping area per plant the same (12, 37, 38). Spacing of plants in the row, as well as plant area, seems to influence tillering. Karper, et al. (18) showed that differences between Milo and Kafir in response to spacing was accounted for by quite different amounts of tillering.

Head size was found to remain the same when area per plant was constant, but row width increased and spacing of plants in the row decreased. This indicates that head size is related directly to area per plant (12).

Burnside, et al. (6) stated that high populations and narrow row spacings cause microclimatic changes that affect temperature, evaporation, and light intensity at the soil surface. They found yields to be positively correlated with plant height, forage yield, population, heads per acre, and weight per 100 seeds.

#### Hybrid Effects on Yield

Since hybrids were not introduced until 1956, less is known about their performance than with grain sorghum varieties.

Yield variations among hybrids are the result of differences in hybrid vigor, amount of tillering, and efficiency in utilizing nutrients and moisture. Some varieties seem to be adapted to vigorous tillering and large heads, while others characteristically develop fewer tillers and smaller heads, associated with thicker planting (20, 35). Laude and Swanson (20) observed that varieties such as Dwarf Yellow Milo, which tiller vigorously do best when spacing is from 12 to 15 inches between plants in rows spaced 40 to 44 inches apart under dryland conditions.

Since sorghum is a short-day species, maturity is hastened with exposure to short days and long nights. Differences in maturity of grain sorghum varieties have been noted to result from differential response to photoperiod, which is genetically controlled (17). More sensitive varieties, such as Hegari and Milo are advanced to a greater extent by decreasing day length (31). Photoperiod insensitive, or later maturing varieties likely have a thermal requirement, which is more responsible for delayed maturity.

Quinby and Karper (29) reported three genes that influence duration of growth,  $ma$ ,  $ma_2$ , and  $ma_3$ . Lateness was found to be dominant to earliness. All four phenotypes resulting from various combinations of these genes result in identical size of plant and duration of growth under 10-hour photoperiods, but differ greatly when daylength is shortened. The phenotypes were designated early, intermediate, late, and very late.

A fourth maturity gene was recently reported by Quinby (28) which was dominant in Hegari and Early Hegari and recessive in Milos.

Complementary action of height and maturity genes results in greater plant size with later maturing hybrids (29, 30). Milo-hegari hybrids usually express extreme vigor in vegetative growth and lateness of maturity (16). Quinby and Karper (30) showed that the heterozygous condition for late maturity also caused a greater stimulation of tillering.

Abbe and Einset (1) reported more rapid cell division in the apical meristem of hybrids compared to grain sorghum varieties, resulting in larger growing points that, in turn, gave rise to larger leaves, stems, and heads. Larger heads would indicate that heterosis was effective after floral initiation, when seed branches and spikelets were being formed.

The maturity of the sorghum plant is directly associated with the number of nodes and leaves on the stalk. Each additional leaf formed delays the

time of flowering about 3-4 days. Also, each additional internode adds several inches to the plant height (31).

Quinby and Karper (32) state that the positive relationship between late maturity and stover yield in grain sorghum does not necessarily exist for late maturity and grain yield. Head size is determined by the size of the growing point out of which it develops. It has been demonstrated that the growing point of a late maturing plant changes very little in diameter in the interval of time between head differentiation in the early and late maturing hybrids. By the time the head is differentiated in the late maturing hybrid soil moisture reserves may have been depleted.

#### Variations in Protein Level

Many factors influence grain sorghum protein content. These include soil fertility, soil type, stand density, general yield level, differences in genetic potential, and interactions of these factors with soil and climate.

Morrison (24) shows the average protein content of hegari and kafir grain as 9.6 and 10.9%, respectively. The crude protein content of No. 2 corn is listed as 8.6%.

While extensive work has been done on grain protein in wheat, little has been done on grain sorghum. With the possible exception of soil fertility, little is known about the contribution of the various factors to the protein content of the grain.

Miller, et al. (23) found protein content to vary from 6.6 to 12.8% and 5.9 to 12.1% in 1961 and 1962, respectively, with 33 hybrids and seven locations in the state. They showed lower protein levels in hybrids than in the old standard varieties. There was a trend toward higher protein levels as the yield decreased, although there was considerable variation in the data.

The genetic influence on protein level in corn has been shown by several workers. The Illinois Agricultural Experiment Station reported that continuous selection in corn can be used to increase or decrease protein content. Doty, et al. (8), despite large fluctuations in two years data, showed that protein character was somewhat controlled by heredity in corn.

Frey (10) reasons that low-protein percentage is completely dominant in corn. In several crosses of high and low protein varieties the  $F_1$  generation did not differ significantly from the low protein parents. The components zein, tryptophan, valine, and isoleucine were also concluded as being completely dominant for the low protein percentage.

Protein content of three varieties of sorghum grain increased with each increment of nitrogen fertilizer applied under irrigated conditions (14, 25). Plant populations of 72,000, 150,000, and 228,000 plants per acre in 30-, 36-, and 24-inch rows, respectively, did not affect grain protein levels (25).

Doty, et al. (7) suggested that seasonal variations of moisture and temperature are quite important in determining the composition of corn grain. Corn grown on several soil types produced different levels of protein, but data were not consistent from year to year and several reversals resulted.

Fraps (9) found protein content of corn to vary from location to location in Texas and tended to be inversely related to the amount of rainfall received from January 1 through July. The correlation coefficient for corn grain protein and rainfall was a significant  $r$  of -0.58.

Greaves and Nelson (11) reported corn grain nitrogen percentages of 1.94 and 2.13 with no manure and 15 tons of manure, respectively. They suggested that corn grain nitrogen content depends mainly on the amount of nitrogen available in the soil. Whitson, et al. (39) reported decreases in nitrogen percentage of mature corn stover with application of manure. However, dry matter per acre was increased from 5,965 to 8,440 pounds.

Wilmer (40) stated that corn varieties may differ markedly in nitrogen content of the mature stover owing to differences in their ability to take up nitrogen or to translocate nitrogen to the grain, or both.

According to data presented by Herron, et al. (14), moisture stress compared to irrigation with and without nitrogen fertilizer produced higher percentages, yet lower yields of nitrogen per acre in the forage throughout the season in grain sorghum.

Little, if any, work has been reported on differential abilities of sorghum varieties or hybrids to accumulate nitrogen or on the sources of nitrogen to the developing grain.

Hanway (13) stated that protein content of corn grain was influenced by the nitrogen in the plant at initial grain development and the amount of nitrogen taken from the soil during grain formation. More than 30% of the nitrogen taken up is contained in the leaves before translocation begins. Approximately 60% of the total amount of nitrogen taken up by the crop is present in the plant by the time of silking.

#### METHODS AND MATERIALS

Six grain sorghum hybrids representing three maturity groups, RS 610 and RS 608 (early), KS 652 and RS 650 (medium), KS 701 and Coop T-700 (late) were planted in fall plowed and weed-free seedbeds in 1964 and 1965. Three pounds of atrazine were sprayed on the soil surface at planting time at all locations except Hutchinson, Kansas, in 1965, where no herbicide was applied.

Locations in 1964 were Manhattan, Powhattan, Belleville, Hutchinson, and Mound Valley, Kansas. Tests at Powhattan and Mound Valley were not harvested as a result of charcoal rot and severe lodging. Results were not recorded for Belleville because of extreme droughty conditions and very poor yields.

A dense stand of sorghum was established in plots of two, 22-foot rows spaced 40 inches apart. All planting was done with small hand planters. When plants were two to five inches in height they were hand thinned to densities of 80, 200, 320, and 440 square inches per plant. These stands correspond to 2, 5, 8, and 11 inches between plants within the row, respectively, or populations of 78,408, 31,363, 19,602, and 14,256 plants per acre, respectively.

A split-plot design with stand densities as main plots and hybrids as sub-plots was utilized. All treatments were replicated four times at each location. Two border rows were used to separate main plots.

Experiments at Manhattan were at the Kansas State University Agronomy Farm. In 1964 grain sorghum was planted May 27 on land to which 120 pounds of nitrogen had previously been applied and worked into the soil. Soil moisture conditions were good at planting time. Soybeans were grown on this area the previous year. In 1965 the experiment was planted May 14 on similar soil, an unnamed alluvial silt loam, to which 80 pounds of nitrogen had been applied. The previous crop was soybeans. A light rain fell within 24 hours after planting, insuring good germination and emergence. For both years cultivation was required in addition to spraying to control weeds.

At Pownall in 1965, 92 pounds of nitrogen was worked into the soil prior to planting on May 27. Soil moisture and temperature were favorable for rapid seedling growth. The soil was a Grundy silty clay loam.

Grain sorghum was planted June 15 at Hutchinson in 1964 and June 17 in 1965. The soil type at the Hutchinson Experimental Field was a Clark loam. During both years subsoil moisture was ample at planting time. The previous crop on the experimental areas in 1964 and 1965 was corn and soybeans, respectively.

Precipitation for the first 60 days after planting at Manhattan in 1964 totaled almost 10 inches. Rainfall during June and July was about normal, but nearly all of the July precipitation fell on the last five days of the month. This was after the early and medium maturing hybrids had begun to bloom and before the late maturing hybrids had started to bloom.

Manhattan precipitation was well above normal in 1965. Within 60 days after planting 17.88 inches of rain fell. Moisture conditions through June and July were conducive to high yields.

Rainfall at Powhattan in 1965 was similar in amount and distribution to that recorded at Manhattan, except that some drought stress may have resulted from low rainfall during the latter part of July and the first part of August. Grain sorghum was planted two weeks later at Powhattan than at Manhattan.

Only 3.53 inches of rain fell during the first 60 days after planting at Hutchinson in 1964. This was decidedly below the average for this period. Despite favorable moisture at planting time, 0.82 inch was the largest rain until August 18. The combination of hot and dry weather resulted in small heads and greatly reduced yields.

Grain sorghum at Hutchinson in 1965 experienced drought stress as a result of the later planting date (June 17) and the low moisture supply during late July and August. Despite good subsoil moisture reserves during the early part of the season, poor yields were obtained.

In 1964 temperatures were below average in June and August and above average in May and July. Average temperatures at Hutchinson for the month of July were probably among the highest recorded for that month. Above 100°F temperatures were reported on 18 days during the month. Temperatures during the 1965 growing season were below normal except for the month of May.

Harvested areas in 1964 included two rows 22 feet in length at each location. Two 15-foot rows constituted the harvest areas in 1965 at each location. At this time the number of heads per harvest area was recorded. Heads were removed by hand with a linoleum knife and later threshed with a small plot thresher. The amount of grain per harvested area was recorded and moisture percentage was immediately determined with an electronic moisture meter.

Samples of threshed grain were taken for nitrogen analysis and for seed weight determinations. Samples for nitrogen determinations were ground, oven dried, and analyzed according to the boric acid modification of the Gunning-Kjeldahl method (2, 3, 34).

Grain sorghum samples of 300 seeds from each plot were counted with an electronic seed counter. Seeds were oven dried at 70°C for 48 hours and then weighed. Weights were converted to and reported as grams per 1,000 seeds.

Average head weight for each harvest area was determined by dividing the number of pounds of grain by the number of heads harvested and multiplying by 454. Head weight was reported as grams per head. Seeds per head was calculated by dividing head weight by seed weight.

In 1965 the experiment was modified to include whole plant sampling at half-bloom and physiologic maturity. Half-bloom was defined as the time when half of the plants in the plot were in some stage of bloom. Four representative plants in some stage of bloom from each plot were cut off at ground level and composited. Sampling was restricted to the first three feet and last four feet of the row. Plants bordering alleys were not sampled. Samples were placed in large ovens to dry. They were then chopped, redried, weighed, and ground. Sub-samples were taken for nitrogen analysis.

At physiologic maturity (maximum dry matter accumulation) whole plant samples were taken in a similar manner as at half-bloom. Plants adjacent to those previously taken or next to alleys were not sampled. Heads were separated from the rest of the plant. The plants were processed as at half-bloom, except that grain was separated, dried, weighed, and sub-sampled for nitrogen analysis.

Total nitrogen determinations were made on the whole plant at half-bloom and physiologic maturity. The amount of nitrogen uptake after half-bloom was determined by the difference in the whole plant nitrogen at maturity and half-bloom. Total nitrogen was determined for the vegetative and grain portions at maturity. The difference in total nitrogen in the plant at half-bloom and in the grain at maturity was reported as the minimum amount of nitrogen translocated to the grain.

Yield data were expressed as pounds per acre on a 12.5% moisture basis. Nitrogen was reported in grams per plant and vegetative yields were reported as grams dry weight per plant. Bloom data were recorded at Manhattan in 1964 and 1965. Statistical analyses were made according to the methods outlined by Snedecor (36) for the split-plot design. Analyses of variance and simple correlations between yield, yield components, nitrogen in the whole plant at half-bloom and maturity, nitrogen taken up after half-bloom, and grain nitrogen were run on an IBM1410 Computer.

#### RESULTS AND DISCUSSION

##### Stand Density and Hybrid Effects on Grain Yield

Manhattan 1964. As shown in Figure 1 and Appendix Tables 1, 2, 3, and 4, grain yield and the components seed weight, seeds per head, and heads per unit area were significantly affected (1% level) by varying plant density.

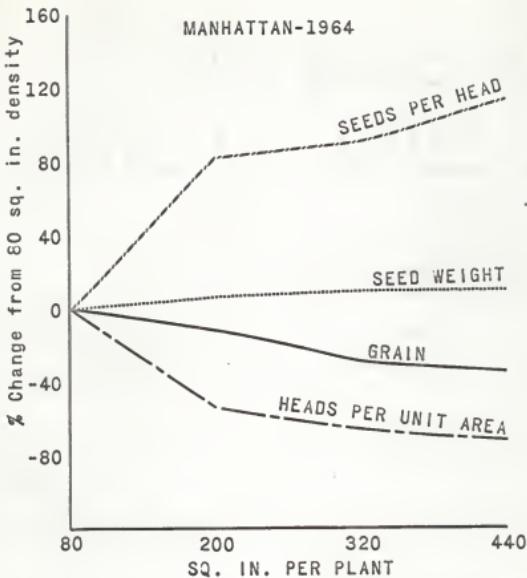


Fig. 1. Mean relative grain yields and yield components over six hybrids as affected by stand density at Manhattan in 1964.

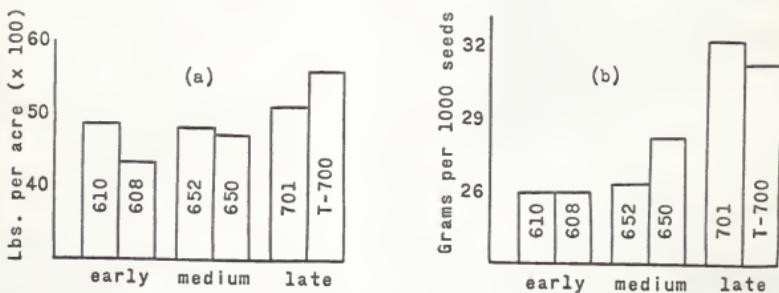


Fig. 2. Effect of hybrids over densities on (a) grain yield per acre and (b) seed weight at Manhattan in 1964.

The highest population (80 square inches per plant) produced the greatest grain yield. Increasing area per plant to 440 square inches decreased yield in a highly significant<sup>1</sup> linear trend. The two lowest populations (320 and 440 square inches per plant) were not significantly different, according to Duncan's New Multiple Range Test. Yields varied from 6,058 to 3,963 pounds per acre for 80 and 440 square inches per plant, respectively.

Seed weight increased in a highly significant linear trend from 26.78 to 29.29 grams per 1,000 seeds with 80 and 440 square inches per plant, respectively. However, only the highest density, which produced the lowest seed weight, was significantly different.

Number of seeds per head increased from 1,478 to 3,163 by increasing area per plant from 80 to 440 square inches. Differences in the two intermediate densities (200 and 320 square inches per plant) were not significant. The greatest increase in seeds per head, 81%, resulted from increasing area per plant from 80 to 200 square inches. Both the linear and quadratic components of plant density were highly significant.

Heads per unit area was inversely related to the number of seeds per head. With each successive increase in plant area there was a significant decrease in heads per unit area. Greatest decrease in number of heads per unit area, 55%, resulted from increasing area per plant from 80 to 200 square inches, corresponding to the greatest increase in number of seeds per head. Very large F values were found for the linear and quadratic components of plant density. The mean number of heads per plant varied from 0.89 to 1.36 for 80 and 440 square inches per plant, respectively.

---

<sup>1</sup>Unless significance level is indicated, the term "highly significant" will mean significance at the 1% level, and "significant" will denote significance at the 5% level.

Grain yield was reduced 35% with decreased density, even though seeds per heads increased sharply and plants were better able to tiller. Tillering, however, failed by a large margin to compensate for decreased stand. Seed weight was the component least affected by changing plant density. The favorable moisture conditions, as discussed earlier, and adequate fertility were important in the development of the large number of heads by the highest population. This agrees with previous workers (14, 26, 27), in that grain sorghum more effectively utilizes an adequate supply of moisture and nutrients when the stand is dense.

Highly significant differences among hybrids on grain yield and the component seed weight were detected at Manhattan in 1964. No hybrid differences in seeds per head or heads per unit area were found. This information is shown in Figs. 2(a) and 2(b); and in Appendix Tables 1 and 2.

Yields varied from 4,343 to 5,608 pounds per acre for RS 608 and Coop T-700, respectively. Coop T-700 produced significantly the highest and RS 608 significantly the lowest grain yield per acre. There were no differences in the other four hybrids. The late maturity group (KS 701 and Coop T-700) out-yielded the early and medium maturity groups, which were not significantly different. There was significance (1% level) for hybrids within maturities, since RS 608 and Coop T-700 were significantly different from the other hybrid in their respective maturity groups.

Seed weight varied from 25.89 to 32.27 grams per 1,000 seeds for RS 610 and KS 701, respectively. KS 701 was significantly the highest, while KS 652, RS 608, and RS 610 were not different and significantly the lowest in seed weight. The late maturity group was significantly higher in seed weight than the medium and early maturity groups.

Superior yields and larger seed weights with the late maturing hybrids may have been favored by late July rainfall after a moisture stress during the earlier part of the month. Differences in maturity, as indicated by bloom data in Appendix Table 54, may have been great enough to allow the late maturing hybrids to better utilize moisture and nutrients. Precipitation was received just after full-bloom of early and medium maturity hybrids and just as the late maturing hybrids were beginning to bloom.

Grain yield was most highly correlated with the component heads per unit area ( $r=.66$ ) at Manhattan in 1964 (Appendix Table 21). Grain yield and seed weight were not significantly correlated. Seed weight and heads per unit area were significantly and negatively correlated ( $r= -.36$ ).

Manhattan 1965. Information on hybrid and plant density effects on grain yield and components at Manhattan in 1965 is presented in Figs. 3, 4, 5, 6, and 7; and in Appendix Tables 5, 6, 7, and 8. Highly significant hybrid x plant density interactions on grain yield and the component seed weight and significant hybrid x plant density interactions on number of seeds per head and heads per unit area were found. Data on interactions are shown in Appendix Tables 22, 23, 24, and 25.

Consistent and highly significant linear increases in grain yield with all hybrids were found with increases in stand density (Appendix Table 22). Differential increases in grain yield among the hybrids with increased stand contributed to the hybrid x plant density interaction. KS 701 increased from 5,336 to 7,362 pounds per acre, or 37.9% with decreased area per plant, while Coop T-700 increased from 5,935 to 6,872 pounds per acre, or only 15.8%. The highest recorded yield was with KS 701 and 80 square inches per plant (7,362 pounds per acre) and the lowest yield was with RS 608 and 440 square inches per plant (5,053 pounds per acre). No individual hybrid was highest or lowest at all plant densities.

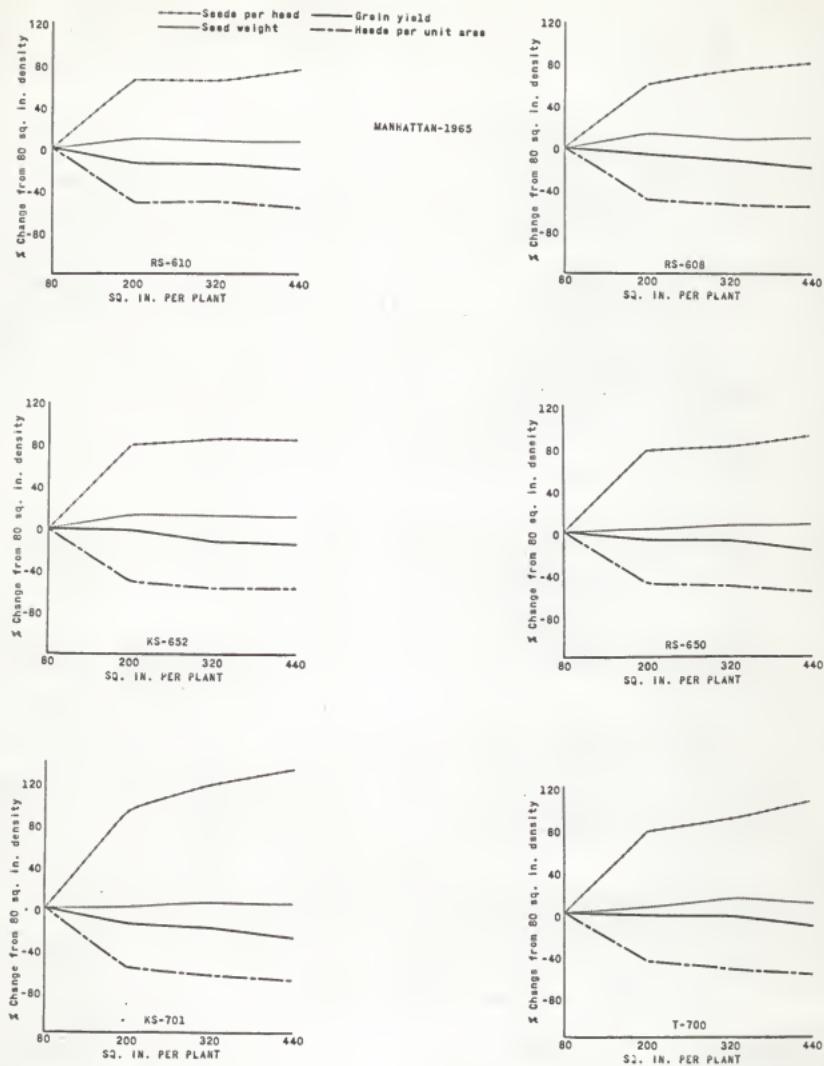


Fig. 3. Mean relative yields and yield components of six hybrids as affected by stand density at Manhattan in 1965.

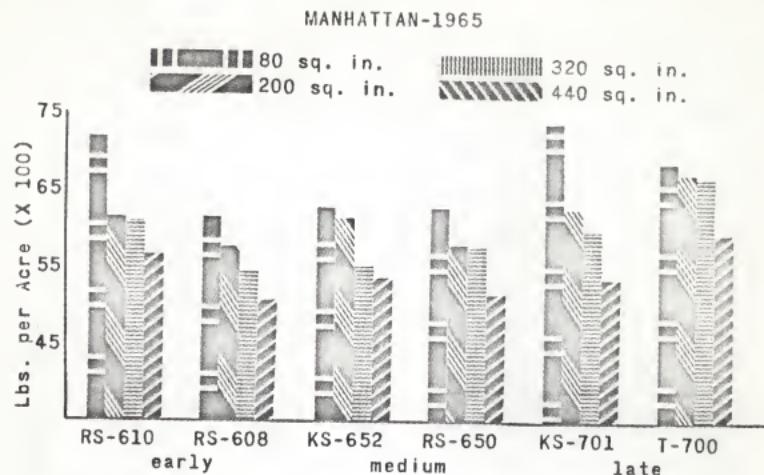


Fig. 4. Comparative grain yields per acre with six hybrids at each plant density at Manhattan in 1965.

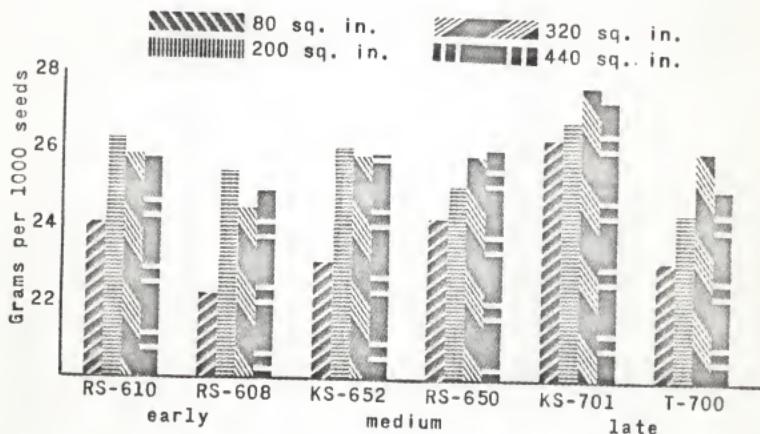


Fig. 5. Influence of hybrids at each plant density on seed weight at Manhattan in 1965.

The late maturity group produced significantly higher grain yields than the medium and early maturity groups at all plant densities (Fig. 4). The early and medium maturity hybrids were significantly different only with the densest stand. Hybrids within maturities were highly significant, mainly as a result of the significantly higher yield of RS 610 over RS 608 with 80 square inches per plant.

The hybrid x plant density interaction on seed weight can be seen in Fig. 5 and Appendix Table 23. In general, seed weight increased with increased area per plant. With the exception of Coop T-700 there were no differences in seed weight with plant areas of 200, 320, and 440 square inches. The interaction arose from the variation in hybrids in response to an increase in area per plant from 80 to 200 square inches. KS 701 and RS 650 were not affected while in all other hybrids seed weight was greatly increased by increasing area per plant from 80 to 200 square inches. Hybrids within maturities and maturity groups were highly significant because of differences in responses within and among maturity groups to changes in plant area.

Hybrid differences contributed more to the hybrid x density interaction than densities, as shown by Appendix Tables 6 and 23. KS 701 was significantly the highest yielder with every stand density except 200 square inches per plant. RS 608 was significantly the lowest in seed weight at 80 and 320 square inches per plant. All other hybrids did not follow a consistent trend.

A highly significant hybrid x density interaction on number of seeds per head was detected and is shown in Appendix Table 7; and in Fig. 6. The interaction is accounted for by a greater increase in the number of seeds per head with increased area per plant for the late maturing hybrids.

There were no significant differences in seeds per head for any of the early and medium maturing hybrids at any of the plant densities. The late maturity group was significantly higher than the early and medium maturity

## MANHATTAN-1965

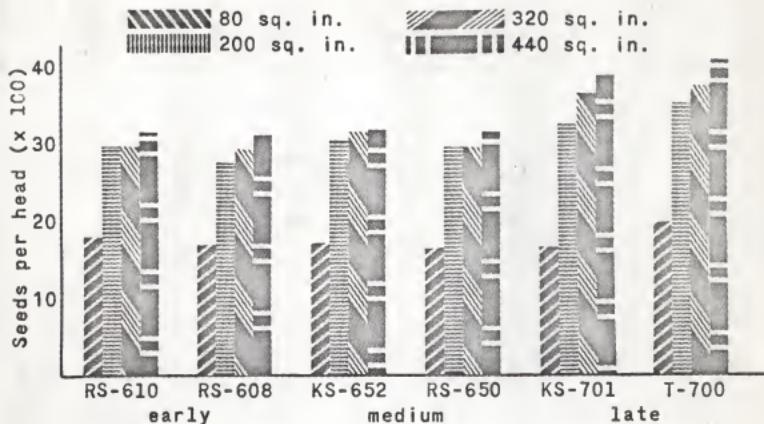


Fig. 6. Influence of hybrids at each plant density on seeds per head at Manhattan in 1965.

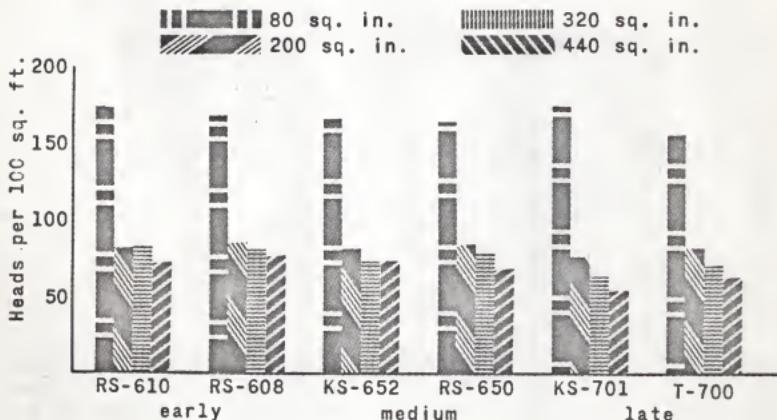


Fig. 7. Influence of hybrids at each plant density on heads per unit area at Manhattan in 1965.

groups at all plant densities. Changing plant density from 320 to 440 square inches per plant had no significant effect on seeds per head for any hybrid except Coop T-700. With every hybrid 80 square inches per plant produced the lowest number of seeds per head.

Influence of hybrids and varying plant density on number of heads per unit area can be seen in Fig. 7; and in Appendix Tables 8 and 25. With every hybrid increasing area from 80 to 200 square inches per plant decreased the number of heads per unit area by approximately one-half. There were no significant differences in hybrids within maturities. Maturities were non-significant with 80 and 200 square inches per plant, but at 320 and 440 square inches per plant early and medium maturity hybrids produced significantly more heads per unit area than the late maturity group.

Grain yield was highly and positively correlated ( $r=.66$ ) with heads per unit area (Appendix Table 21) and negatively correlated ( $r= -.31$  and  $-.48$ ) with seed weight and seeds per head, respectively. Seeds per head and heads per unit area were very highly correlated ( $r= -.93$ ).

Increases in yield with all hybrids by increasing number of plants per unit area at Manhattan in 1965 agrees with the results from the previous year and with those of other workers. Late maturing hybrids were able to outyield early and medium maturing hybrids at all plant densities due to a greater number of seeds per head. Development of a larger number of seeds with the late maturing hybrids may be associated with the longer duration of growth. Data in Appendix Table 55 show date of half-bloom to be delayed about four days with the late maturity group at Manhattan in 1965. Early and medium maturity groups were not significantly different in grain yield or time to half-bloom.

Powhatan 1965. Yield and yield components as affected by plant density and hybrids are shown in Figs. 8 and 9; and in Appendix Tables 9, 10, 11, and 12. A significant interaction of hybrids and densities on grain yield and highly significant hybrid x density interactions on the three yield components resulted and can be seen in Appendix Tables 26, 27, 28, and 29.

With every hybrid but RS 610 there were no significant differences in grain yields with plant densities of 80, 200, and 320 square inches per plant. RS 610 produced the highest grain yield with 320 square inches per plant. Grain yields were lowest for all hybrids except RS 608 and KS 652 with 440 square inches per plant. KS 652 produced equal yields with all plant densities. No hybrid was found to be significantly highest or lowest in grain production with any of the plant densities. Coop T-700 was one of the highest grain yielders with each plant density, however. Grain yields ranged from 7,220 to 5,016 pounds per acre with RS 610 at 320 square inches per plant and KS 701 at 440 square inches per plant, respectively.

More variation was observed for hybrids within maturities than among maturities. Maturities were significant at the 5% level. Most of the hybrids within maturities variation was contributed by the differences in RS 610 and RS 608 means with 320 square inches per plant. The late maturity group produced significantly higher grain yields with the two densest populations, but was not significantly different from either early or medium maturity groups at the two thinnest populations.

Seed weight tended to increase with decreased area per plant, as shown in Figs. 8 and 10 and Appendix Table 27. Late maturing hybrids, KS 701 and Coop T-700, which varied from 24.36 to 30.00 and 20.97 to 26.22 grams per 1,000 seeds increased the greatest amount with decreased area per plant, giving rise to the highly significant hybrid x density interaction on seed

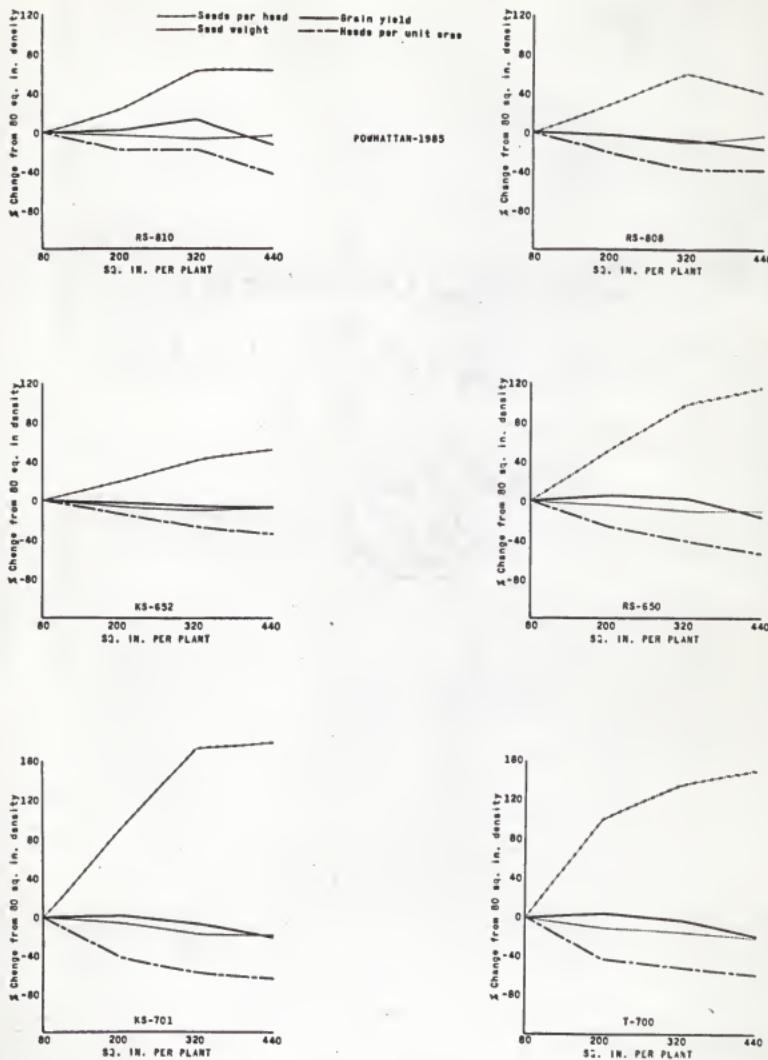


Fig. 8. Mean relative grain yields and yield components of six hybrids as affected by stand density at Powhatan in 1965.

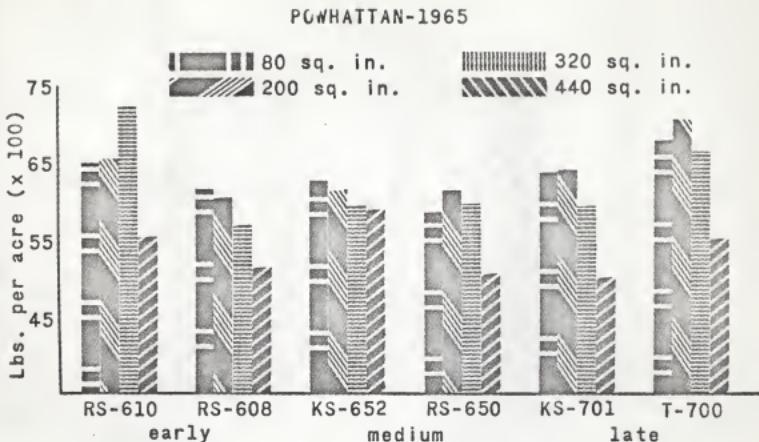


Fig. 9. Comparative grain yields per acre with six hybrids at each plant density at Powhattan in 1965.

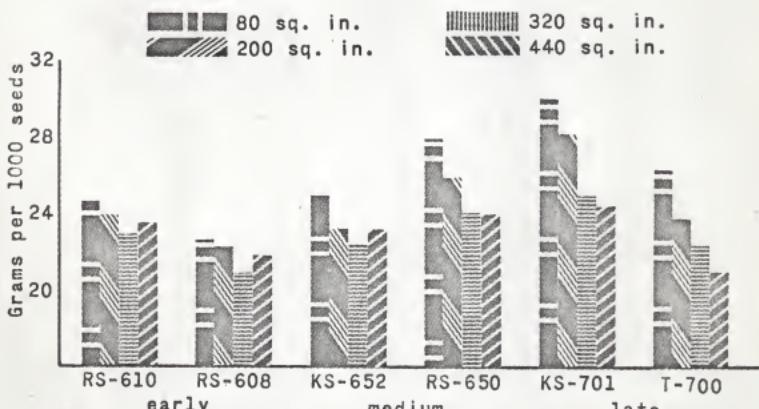


Fig. 10. Influence of hybrids at each plant density on seed weight at Powhattan in 1965.

weight. With all hybrids there were no significant differences between 320 and 440 square inches per plant. Plant densities of 80 and 440 square inches per plant produced the highest and lowest seed weights, respectively, with the two late maturity hybrids and RS 650. There were no differences in seed weight among the stand densities with RS 610.

With 80 square inches per plant each successively later maturity group produced greater seed weight. With 440 square inches per plant there were no differences among maturity groups on seed weight. With 200 and 320 square inches per plant late and medium maturity groups were not significantly different and were greater than the early maturity group.

A larger increase in number of seeds per head in the late maturity hybrids with increased plant area resulted in a highly significant hybrid  $\times$  density interaction, as shown in Figs. 8 and 11; and in Appendix Table 28.

Late maturity hybrids increased from 1,516 and 1,248 to 3,808 and 3,475 seeds per head for Coop T-700 and KS 701, respectively. While late maturity hybrids increased 164.5%, medium and early maturity groups increased 82.5 and 52.0%, respectively. The late maturity group resulted in a greater number of seeds per head than early and medium maturity groups at every plant density except at 80 square inches per plant, where the early maturity group was significantly higher. Early and medium maturity groups were not significantly different, except at 320 square inches per plant, where the early maturity group produced significantly more seeds per head.

Changing plant area from 320 to 440 square inches did not significantly affect the number of seeds per head with any hybrid. With every hybrid but KS 652 significantly the lowest number of seeds per head resulted from 80 square inches per plant.

## POWHATTAN-1965

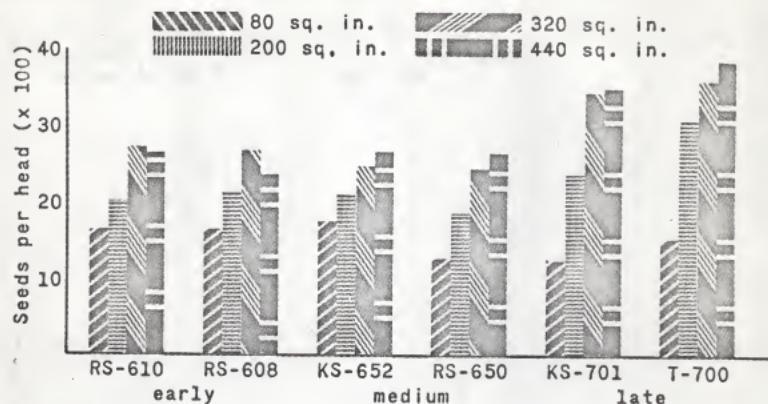


Fig. 11. Influence of hybrids at each plant density on seeds per head at Powhatan in 1965.

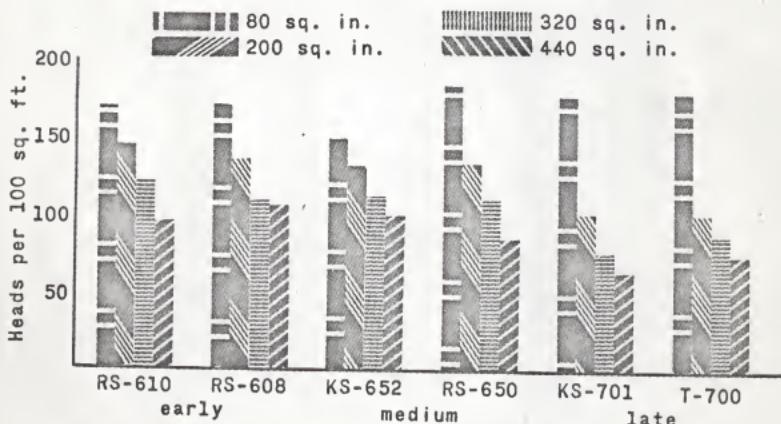


Fig. 12. Influence of hybrids at each plant density on heads per unit area at Powhatan in 1965.

Appendix Tables 12 and 29 present data on the highly significant hybrid  $\times$  density interaction on heads per unit area. The nature of the interaction can also be seen in Fig. 12.

At every plant density early and medium maturity groups were nonsignificant. The late maturity group produced significantly fewer heads per unit area than the early and medium maturity groups with 200, 320, and 440 square inches per plant. The late maturity group was significantly higher than the medium maturity group at 80 square inches per plant. Hybrids within maturities were not significant.

Number of heads per 100 square feet decreased from 177.7 to 68.4 with the late maturity group by increasing area per plant from 80 to 440 square inches per plant. Number of heads per plant increased from 0.99 to 2.07 over the same range of densities. Medium and early maturity groups decreased from 166.8 to 92.4 and from 170.4 to 100.2 heads per unit area, respectively. At the same time the number of heads per plant increased from 0.93 to 2.80 and from 0.95 to 30.4 with medium and early maturity groups, respectively.

Comparisons of grain yield with the components seed weight and heads per unit area resulted in significant correlations ( $r=.23$  and  $-.42$ , respectively), as shown in Appendix Table 21. No correlation appeared between grain yield and number of seeds per head. Seeds per head and heads per unit area were highly and negatively correlated ( $r= -.90$ ).

Much less variation was found in grain yield than in the yield components at Powhatan in 1965. The very high and negative correlation of seeds per head and heads per unit area indicates that as heads per unit area, the first component to be determined, increases, seeds per head decreases. This was accentuated more in the late maturity group at the densest stand and probably was the reason for the greater seed weight.

With increased area per plant early and medium maturities tended to follow the same pattern and level in heads per unit area and seeds per head. Medium maturing hybrids increased more in seed weight. Heads per unit area decreased more with late maturity hybrids with increased plant area because of less ability to produce tillers. This resulted in a greater increase in number of seeds per head and a corresponding decrease in seed weight.

Hutchinson 1964. Although plant densities had no effect on grain yield, a significant hybrid x density interaction was detected (Appendix Tables 13 and 30). Hybrid grain yields within plant densities were quite variable (Fig. 14). Most variation was found with 80 square inches per plant, where yields ranged from 2,465 to 3,653 pounds per acre. There were no significant differences in hybrids with 320 square inches per plant.

Hybrids within maturities were highly significant and most of the variation was contributed by the variation of the medium maturity hybrid means. Hybrid maturities were significant (5% level). This was accounted for by the significantly higher yield of the late maturity group over the medium and early maturity groups, which did not differ significantly.

A large F value was found for the effect of plant densities on seed weight (Appendix Table 14). Seed weight ranged from 22.08 to 26.35 grams per 1,000 seeds and was significantly lower for 80 than for 200, 320, and 440 square inches per plant, which did not differ significantly (Fig. 13). Mean seed weights for hybrids (Fig. 15) varied from 24.36 to 25.90 and no individual hybrid or maturity group was significantly high or low. All of the hybrid variation was found to be in hybrids within maturities.

Larger increases in number of seeds per head with each earlier maturity group as area per plant increased accounted for a highly significant hybrid x density interaction (Appendix Tables 15 and 31). Increased area per plant from

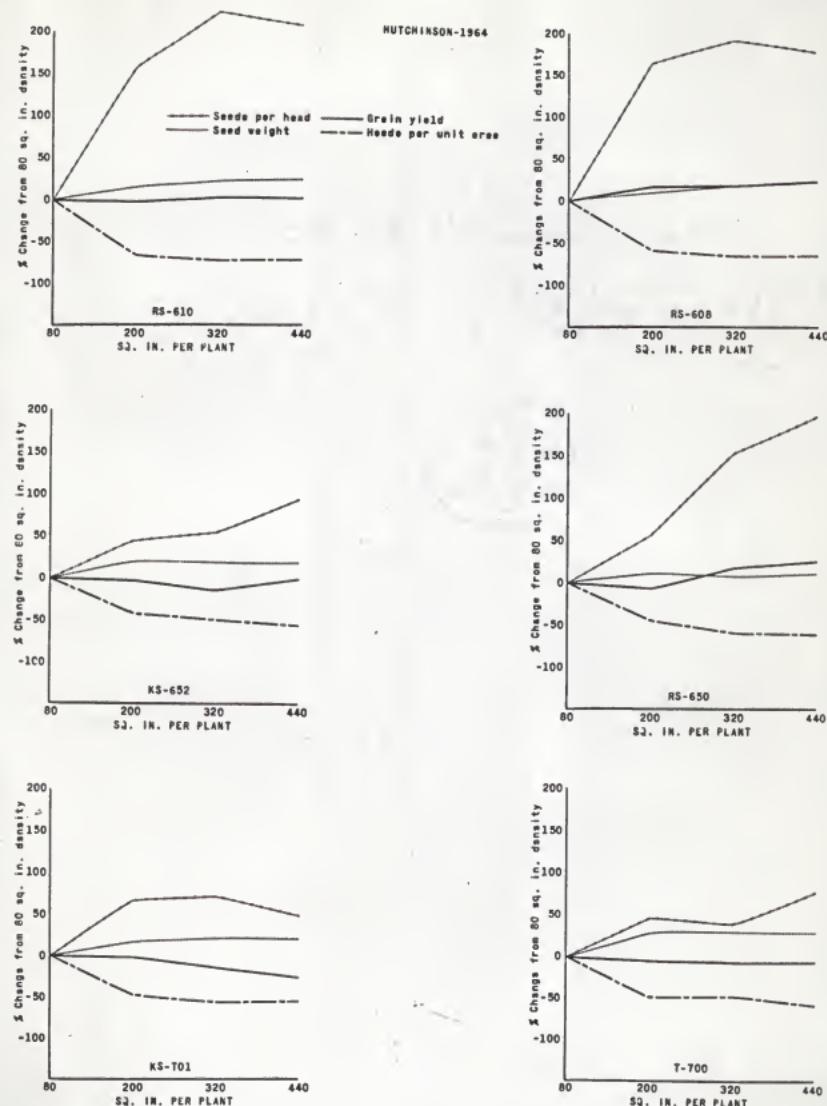


Fig. 13. Mean relative grain yields and yield components of six hybrids as affected by stand density at Hutchinson in 1964.

## HUTCHINSON-1964

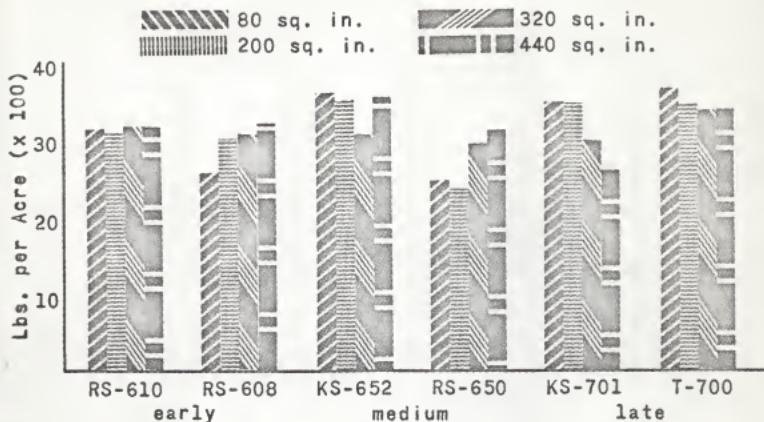


Fig. 14. Comparative grain yields per acre with six hybrids at each plant density at Hutchinson in 1964.

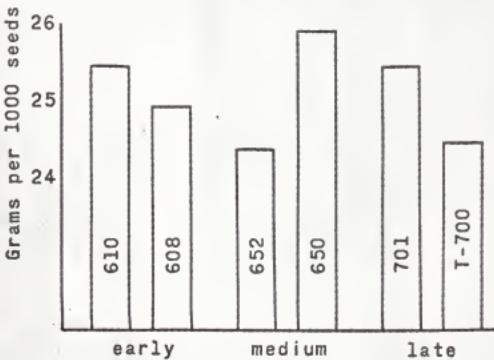


Fig. 15. Influence of hybrids over plant densities on seed weight at Hutchinson in 1964.

80 to 320 square inches increased the number of seeds per head with most hybrids. Number of seeds per head was not significantly different for any hybrid except Coop T-700 with 320 and 440 square inches per plant. Late maturity hybrids were significantly higher than early and medium at 80 square inches per plant, but significantly lower than medium at 200 and early at 320 square inches per plant. There were no maturity differences with 440 square inches per plant.

Differential hybrid responses to plant density variation gave rise to a highly significant hybrid  $\times$  density interaction on number of heads per unit area, as illustrated in Fig. 17 and Appendix Tables 16 and 32. Largest variation among hybrids was at the densest population, which ranged from 246.5 to 167.8 heads per 100 square feet for RS 610 and Coop T-700, respectively. With 80 square inches per plant the early maturity group produced more heads per unit area than the medium, which in turn, produced more heads per unit area than the late maturity group. There were no differences in maturity groups or hybrids at the thinnest stand. Number of heads per 100 square feet ranged from 69.3 to 85.5 with 440 square inches per plant. Mean number of heads per plant varied from 1.32 to 2.77, 1.16 to 2.57, and 0.99 to 2.33 for early, medium, and late maturities, respectively.

The only component significantly correlated with grain yield at Hutchinson in 1964 was seeds per head (Appendix Table 21). The  $r$  value was 0.43. Seed weight and seeds per head were positively correlated, while seed weight and heads per unit area were negatively correlated. Seeds per head and heads per unit area were also negatively correlated.

Prevailing hot and dry weather at Hutchinson in 1964 evidently was responsible for the large reduction in seeds per head and seed weight with decreased area per plant. Even though number of heads per unit area decreased greatly

## HUTCHINSON-1964

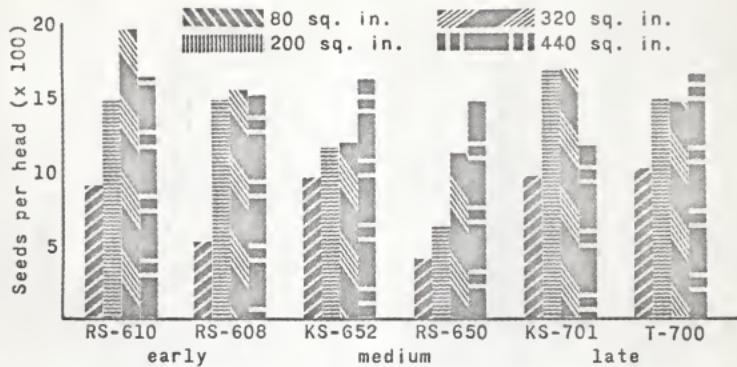


Fig. 16. Influence of hybrids at each plant density on seeds per head at Hutchinson in 1964.

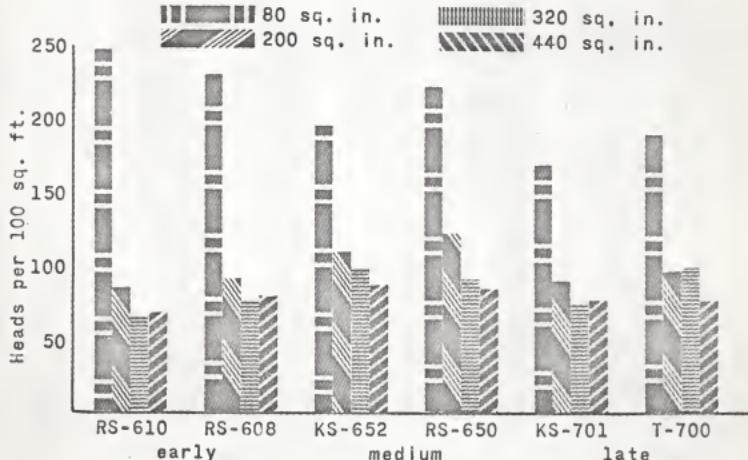


Fig. 17. Influence of hybrids at each plant density on heads per unit area at Hutchinson in 1964.

from 80 to 200 square inches per plant, tillering was quite extensive and aided in equalizing grain yields of the three lowest populations.

Late maturity hybrids tillered very little at the densest stand, while tillers contributed to the number of heads per unit area with the early and medium maturities. This difference in tillering is likely the reason for the increased number of heads with the late maturity hybrids at the densest stand.

The fact that dense stands fail to outyield thinner stands of grain sorghum in dry seasons, as reported by previous workers, seems to be due to the influence on the components seed weight and seeds per head to a larger extent than differences in heads per unit area.

Hutchinson 1965. Figs. 18 and 19 and Appendix Tables 17, 18, 19, and 20 show hybrid and plant density effects on grain yield and components at Hutchinson in 1965. Hybrid differences on grain yield (Fig. 19(a)) were highly significant. Hybrid means ranged from 4,029 to 3,106 pounds per acre with Coop T-700 and RS 608, respectively. Means for maturity groups were 3,878, 3,558, and 3,366 pounds per acre for late, medium, and early maturities, respectively. Late maturity hybrids were significantly highest and early maturity hybrids were significantly lowest in grain yield. The highly significant hybrids within maturities variation was accounted for by the difference in the means of the two early maturing hybrids, RS 610 and RS 608.

Plant density means ranged from 3,866 to 3,349 pounds per acre with 200 and 440 square inches per plant, respectively. Plant area of 200 square inches produced the highest yield, while 440 square inches produced the lowest. Areas of 80 and 320 square inches were not significantly different. Both linear and quadratic functions of plant density were highly significant.

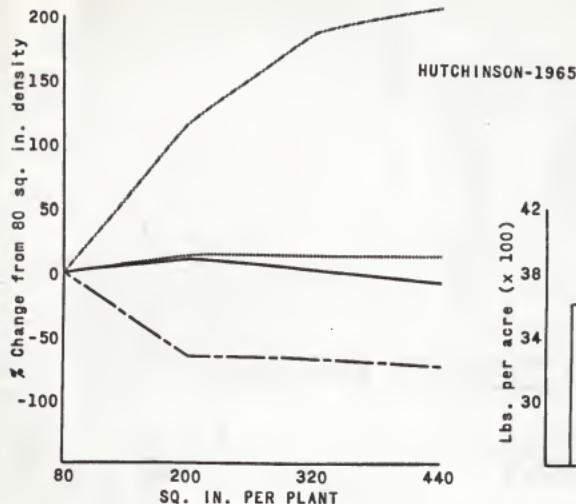


Fig. 18. Mean relative grain yields and yield components over six hybrids as affected by stand density at Hutchinson in 1965.

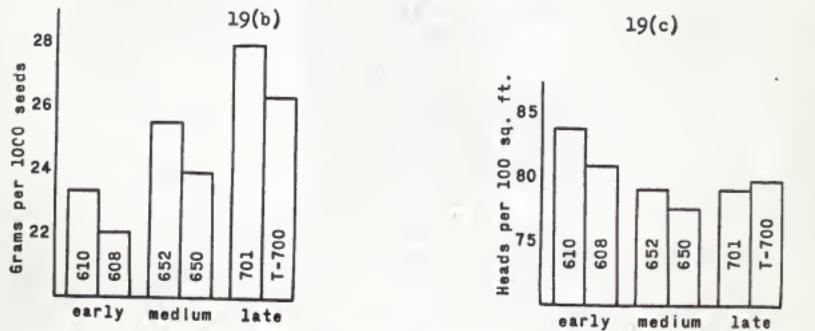


Fig. 19. Influence of six hybrids over densities on (a) grain yield per acre, (b) seed weight, (c) heads per unit area.

Highly significant differences among hybrids and plant densities on seed weight were found (Figs. 18 and 19(b) and Appendix Table 18). Seed weight varied from 27.97 to 22.02 grams per 1,000 seeds for KS 701 and RS 608, respectively. These were significantly the highest and lowest seed weights among hybrids. Seed weight was highest for the late maturity group and lowest for the early maturity group. Although hybrids within maturities produced a highly significant F value, the magnitude was not nearly as great as the maturities F value.

Seed weights over plant densities varied from 25.54 to 23.01 for 320 and 440 square inches per plant, respectively. Seed weights of the three densest populations were not significantly different, but all were significantly higher than with the thinnest stand. Both linear and quadratic functions were highly significant.

Hybrids did not significantly differ in number of seeds per head. Number of seeds per head ranged from 3,219 to 1,049 for 440 and 80 square inches per plant, respectively. With each increase in plant area the number of seeds per head was significantly increased, (Fig. 18), resulting in the very large F value for plant densities and the highly significant linear and quadratic functions.

Variations among hybrids in heads per unit area are shown in Fig. 19(c) and Appendix Table 20. Hybrid means ranged from 83.8 to 77.6 heads per 100 square feet for RS 610 and RS 650, respectively. The early maturity group produced significantly more heads per unit area than the medium and late maturity groups, which were not significantly different. Hybrids within maturities were not significantly different.

Increasing area per plant from 80 to 440 square inches decreased the number of heads per 100 square feet from 158 to 43. The greatest decrease in heads resulted from changing area per plant from 80 to 200 square inches (Fig. 18).

Mean number of heads per plant varied from 0.88 to 1.30 for 80 and 440 square inches per plant, respectively.

Seed weight was the only component significantly correlated with grain yield ( $r=.39$ ) at Hutchinson in 1965. Seed weight and heads per unit area were highly and negatively correlated ( $r=.38$ ). An extremely high and negative correlation ( $r= -.93$ ) was found between seeds per head and heads per unit area.

#### Dry Matter

Manhattan 1965. Dry matter accumulation per plant at half-bloom is shown in Appendix Table 33. Increasing area per plant from 80 to 440 square inches increased dry matter accumulation per plant from 47.9 to 86.1 grams. The greatest increase in dry matter per plant was obtained by increasing area per plant from 80 to 200 square inches. The two lowest populations (320 and 440 square inches per plant) were not significantly different. Linear and quadratic functions of plant density were highly significant.

Dry matter per plant increased with lateness of maturity. Values of 82.4, 70.2, and 65.0 grams per plant were recorded for late, medium, and early maturity groups, respectively. All three values were significantly different from one another. Hybrids within maturities variation was highly significant, mainly due to the difference in the medium maturity means.

Bloom data (Appendix Table 55) for Manhattan in 1965 show almost four days delay in half-bloom with late maturing hybrids. This longer duration of growth and the favorable moisture and temperature conditions prior to bloom would favor dry matter accumulation in late maturing hybrids. However, bloom dates for early and medium maturity hybrids were not significantly different. Medium maturing hybrids were able to accumulate more dry matter in the same amount of time.

Powhattan 1965. Dry matter per plant at half-bloom increased significantly with each increase in plant area and ranged from 51.0 to 75.9 grams with 80 and 440 square inches per plant, respectively (Appendix Table 34). Greatest increase in dry weight per plant was found by increasing area per plant from 80 to 200 square inches.

Late maturity hybrids with means of 83.9 and 81.2 grams per plant were significantly higher than the early and medium maturing hybrids, which were not significantly different. Early and medium maturity groups accumulated 56.5 and 59.5 grams per plant, respectively.

Hutchinson 1965. Dry weights per plant at Hutchinson in 1965 are shown in Appendix Table 35. Dry matter accumulation increased from 46.2 to 75.3 grams per plant by increasing area per plant from 80 to 440 square inches. Plant areas of 200 and 320 square inches were not significantly different in dry weight. Dry weights of 77.1, 60.2, and 50.2 grams per plant were found with late, medium, and early maturity groups, each significantly different from the other.

#### Total Nitrogen

Manhattan 1965. Total nitrogen per plant at half-bloom is shown in Fig. 20 and Appendix Table 36. As expected, plant densities had a large influence on total nitrogen per plant. Increasing area per plant from 80 to 440 square inches increased total nitrogen per plant from 0.92 to 1.89 grams (Fig. 20(a)). Values for 320 and 440 square inches per plant were not significantly different, however.

Hybrids ranged from 1.72 to 1.38 grams nitrogen per plant for Coop T-700 and RS 610, respectively (Fig. 20(b)). The late maturity group (KS 701 and Coop T-700) was found to accumulate significantly more nitrogen per plant than the early and medium maturity hybrids, which did not differ.

## MANHATTAN-1965

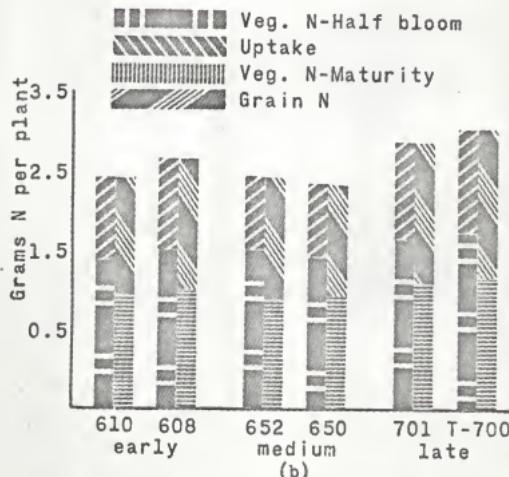
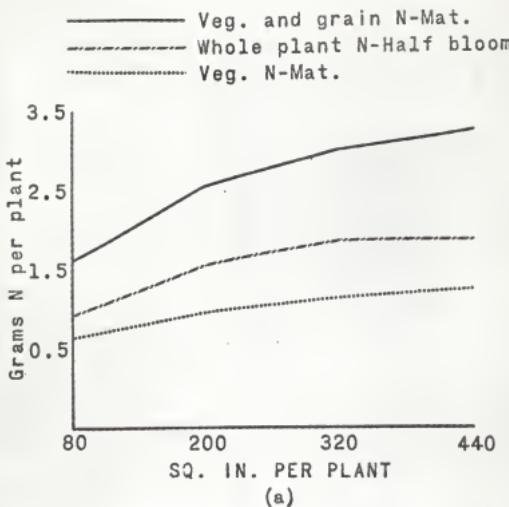


Fig. 20. Total nitrogen per plant as affected by (a) plant densities and (b) hybrids at Manhattan in 1965.

Data for the accumulation of nitrogen per plant at physiologic maturity are presented in Fig. 20 and Appendix Table 34. Results were similar to those for nitrogen at half-bloom, except that nitrogen variation per plant was greater at maturity. Increasing area per plant from 80 to 440 square inches increased nitrogen per plant from 1.60 to 3.28 grams (Fig. 20(a)). Each successive increased plant area produced significantly more nitrogen per plant at physiologic maturity.

Hybrids varied from 3.02 to 2.35 grams nitrogen per plant for Coop T-700 and RS 650, respectively (Fig 20(b)). Nitrogen per plant was significantly highest with the late maturity group and significantly lowest with the medium maturity group. Values for maturity groups were 2.94, 2.54, and 2.36 grams nitrogen per plant for late, early, and medium maturities, respectively.

Total nitrogen in the plant at maturity was divided into vegetative and grain portions, as shown in Fig. 20(b). Total nitrogen in the vegetative parts followed the same pattern as total nitrogen of the whole plant. Each increase in plant area resulted in significantly greater nitrogen per plant. The range was from 0.62 to 1.26 grams. Nitrogen per plant ranged from 1.15 to 0.89 for Coop T-700 and RS 652, respectively. The greatest amount of nitrogen per plant was found with the late maturity hybrids and the least with the early maturity hybrids.

Total nitrogen per plant varied from 0.99 to 2.02 grams in the grain at physiologic maturity with area per plant ranging from 80 to 440 square inches. Plant densities of 320 and 440 square inches did not differ significantly. The late maturity group with 1.82 grams nitrogen per plant in the grain was significantly highest and the medium maturity group with 1.48 grams nitrogen per plant was significantly the lowest.

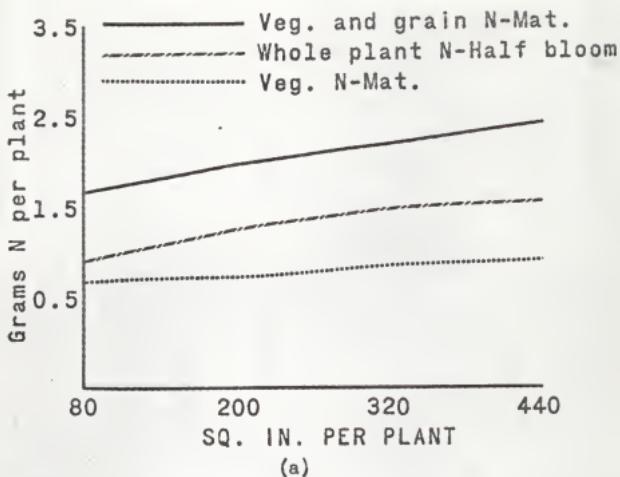
Uptake of nitrogen per plant from half-bloom to physiologic maturity

was measured by the difference in total nitrogen in the plant at physiologic maturity and at half-bloom. As shown in Fig. 20(b), the late maturity group was able to take up a greater amount of nitrogen after half-bloom. The late maturity group took up 1.25 grams nitrogen per plant, while the medium maturity, which was significantly the lowest, took up 0.93 grams nitrogen per plant. Uptake increased from 0.68 to 1.39 grams per plant by increasing area per plant from 80 to 440 square inches. The two lowest populations were not significantly different.

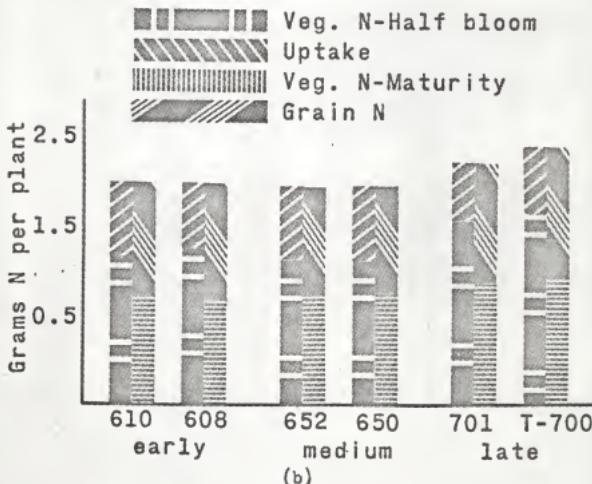
The measurable amount of translocation of the nitrogen in the plant at half-bloom was determined by the difference in total nitrogen in the plant at half-bloom and in the vegetative parts at maturity (Fig. 20(b)). Translocation varied from 0.57 to 0.46 grams per plant with hybrids, but these values were not significantly different. As would be expected, greater amounts of nitrogen were translocated from plants with greater area. However, the three lowest populations (greatest areas) were not significantly different. Translocation per plant ranged from 0.63 to 0.30 grams for 320 and 80 square inches per plant, respectively.

Powhatan 1965. Greater amounts of nitrogen per plant were accumulated by late maturing hybrids (Fig. 21) at half-bloom. Greater increases in nitrogen with late maturing hybrids by increasing area per plant accounted for the highly significant hybrid x density interaction (Appendix Table 42). The late maturity group was significantly higher than the medium, but not different from the early maturity group with 80 square inches per plant. At all other plant densities the late maturity hybrids accumulated significantly more nitrogen per plant than the early and medium maturity hybrids, which did not differ significantly.

## POWHATTAN-1965



(a)



(b)

Fig. 21. Total nitrogen per plant as affected by (a) plant densities and (b) hybrids at Powhatan in 1965.

Total nitrogen per plant at half-bloom increased with increasing area per plant. Plant area of 80 square inches produced the lowest amount of nitrogen per plant with every hybrid. Plant areas of 320 and 440 square inches were not different with any hybrid.

Nitrogen accumulation at physiologic maturity is shown in Fig. 21. Total nitrogen in the whole plant is represented by the height of the second bar of each hybrid. Late maturing hybrids were able to accumulate significantly more nitrogen per plant than early and medium maturity hybrids, which were not significantly different. Values of 2.29, 1.98, and 1.93 grams per plant were found for late, medium, and early maturity groups, respectively. By increasing plant area from 80 to 440 square inches total nitrogen per plant increased from 1.67 to 2.41 grams. Each increase in plant area produced a significant increase in total nitrogen per plant.

Total nitrogen in the vegetative parts at physiologic maturity (Fig. 21) was highest in the late maturity hybrids, which contained 0.90 grams per plant. Medium and early maturity hybrids were not significantly different. Total nitrogen increased significantly with each increase in plant area and varied from 0.65 to 0.91 grams per plant with 80 and 440 square inches per plant, respectively.

Total nitrogen per plant in the grain was significantly higher for each later maturity group (Fig. 21). Early, medium, and late maturity groups produced 1.19, 1.28, and 1.39 grams of nitrogen per plant in the grain at physiologic maturity. Plant density effects, as shown in Appendix Table 45, were rather small. Total nitrogen in the grain was increased from 1.02 to 1.50 grams per plant by increasing area per plant from 80 to 440 square inches. However, the two highest and the two lowest populations were not significantly different.

Uptake of nitrogen from half-bloom to maturity is shown in Fig. 21 by the difference in the height of the second bar and the height of the first bar representing total nitrogen in the plant at half-bloom. There were no differences in hybrids or densities in the ability to take up nitrogen after half-bloom, as shown statistically in Appendix Table 46. Values ranged from 0.67 to 0.83 grams nitrogen per plant for hybrids and from 0.71 to 0.85 grams nitrogen per plant for plant densities.

Translocation of nitrogen from the plant at half-bloom was extremely variable for plant densities and hybrids, as shown in Appendix Table 47. Greater amounts of nitrogen translocated by late maturities with increased area per plant resulted in a highly significant hybrid x density interaction. Translocation was greatest with the late maturity group for all plant densities except 80 square inches per plant. There were no hybrid differences at the highest population. Early and medium were not different at the two highest populations but the early maturity group was significantly higher at the two lowest populations. With area per plant increasing from 80 to 440 square inches, early, medium, and late maturity groups ranged from 0.18 to 0.48, 0.27 to 0.64, and 0.28 to 0.85 grams per plant, respectively.

Late maturity hybrids at Manhattan in 1965 were able to accumulate more nitrogen per plant than medium and early maturing hybrids. On the basis of bloom data (Appendix Table 55), the late maturing hybrids had more time in which to take up nitrogen. Late maturity hybrids were also able to take up more nitrogen from half-bloom to physiologic maturity. This can be accounted for by the longer time interval from half-bloom to physiologic maturity associated with late maturing hybrids.

Hutchinson 1965. Significantly more nitrogen per plant was accumulated by half-bloom with each later maturity group, as shown in Fig. 22(b) and Appendix Table 48. There were no significant differences in hybrids within maturities. Late, medium, and early maturity groups accumulated 1.36, 1.05, and 0.85 grams of nitrogen per plant, respectively. By increasing area per plant from 80 to 440 square inches nitrogen per plant increased from 0.73 to 1.39 grams (Fig. 22(a)). Each larger area per plant produced significantly more nitrogen per plant.

Total nitrogen per plant variations at physiologic maturity are illustrated in Fig. 22 and Appendix Table 49. Nitrogen amounts among hybrids varied from 1.93 to 2.13. This difference was not significant. Each larger area per plant produced significantly more nitrogen (Fig. 22(a)). Values of 1.15 and 2.66 grams per plant resulted from 80 and 440 square inches per plant, respectively.

Fig. 22(b) shows yields of nitrogen per plant at physiologic maturity in the vegetative parts. There is less variation among hybrids than in the plant at half-bloom. Late, medium, and early maturity groups contained 0.79, 0.78, and 0.70 grams nitrogen per plant, respectively. Late and medium maturities were not different, but significantly higher in nitrogen than the early maturity group. Each increase in plant area resulted in a significant increase in nitrogen per plant, as shown in Fig. 22(a). Nitrogen per plant varied from 0.44 to 1.01 grams with increased area per plant.

Nitrogen per plant in the grain among hybrids ranged from 1.20 to 1.36 grams, but was not significant (Fig. 22(b)). Each increased plant area increased nitrogen per plant in the grain, as shown by the difference in upper and lower lines in Fig. 22(a). Nitrogen per plant ranged from 0.70 to 1.65 grams for 80 and 440 square inches per plant, respectively.

## HUTCHINSON-1965

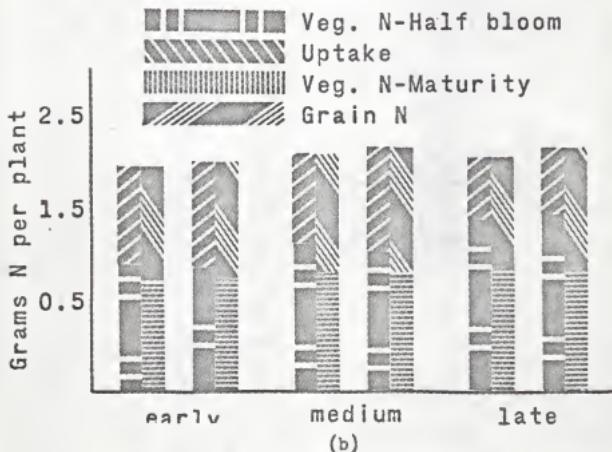
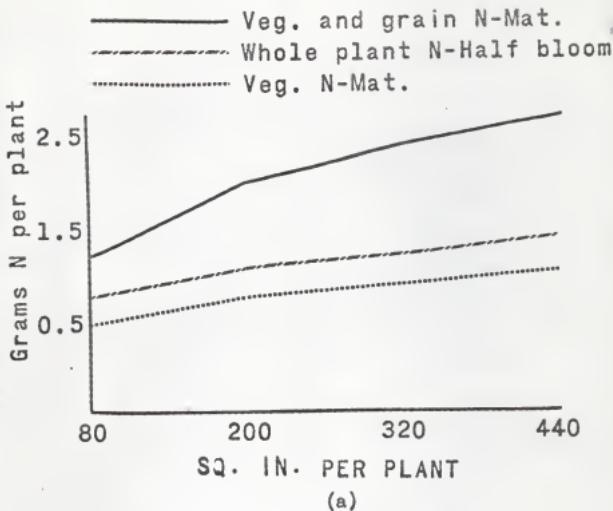


Fig. 22. Total nitrogen per plant as affected by (a) plant densities and (b) hybrids at Hutchinson in 1965.

Nitrogen uptake per plant from half-bloom to physiologic maturity is shown in Fig. 22(b) for hybrids and for plant densities in Fig. 22(a) by the difference in the upper two lines. Early and medium maturity groups were not significantly different but took up a greater amount of nitrogen after half-bloom than the late maturity group. Nitrogen uptake for early, medium, and late maturities were 1.09, 1.03, and 0.70 grams, respectively. Nitrogen uptake varied from 1.27 to 0.47 grams for 440 and 80 square inches per plant, respectively. The two lowest populations were not significantly different, but took up more nitrogen than the two highest populations. The highest population took up significantly the least amount of nitrogen per plant.

Measurable amount of translocation from the plant at half-bloom to the grain at maturity is shown in Fig. 22 and Appendix Table 53. The late maturity group translocated the most nitrogen per plant while the early maturity group translocated the least. This is shown in Fig. 22(b) by the difference in amount of nitrogen per plant at half-bloom and the amount of nitrogen in the vegetative parts at maturity. Values of 0.56, 0.21, and 0.16 grams of nitrogen per plant were found for late, medium, and early maturity groups, respectively. There were no differences in translocation of nitrogen by changing plant density as illustrated in Fig. 22(a) by the difference in the two lower lines and shown statistically in Appendix Table 53.

Late maturity hybrids accumulated more nitrogen per plant by half-bloom than early and medium maturity hybrids but were able to take up less nitrogen after half-bloom. This resulted in an equalizing in the amount of nitrogen per plant with hybrids at physiologic maturity.

It appears that the late maturity hybrids had depleted the available nitrogen by half-bloom and were not able to incorporate any more nitrogen in

the grain than early and medium hybrids. Each later maturity hybrid increased the amount of nitrogen accumulated to half-bloom. This may be due to the longer duration of growth, as explained earlier.

The proportion of nitrogen taken up after half-bloom that appeared in the grain and vegetative parts at maturity could not be determined. Not all of the nitrogen translocated from the above-ground parts to the grain could be accounted for. There is evidence that a large amount of the grain nitrogen originates from nitrogen uptake after half-bloom.

#### Nitrogen Percentage

Manhattan 1964. Data showing percent Kjeldahl nitrogen in the grain are shown in Appendix Table 56. Nitrogen percentages ranged from 2.17 to 2.02 for 440 and 80 square inches per plant, respectively. The two lowest, the two intermediate, and the two highest populations were not significantly different. The linear function of plant densities was highly significant. RS 608 was significantly the highest in nitrogen percentage, while RS 610 was the lowest. Early and late maturity groups were the same and significantly higher than the medium maturity group.

Manhattan 1965. As shown in Appendix Table 57, nitrogen percentage decreased with each increased area per plant and varied from 1.82 to 2.00 for 80 and 200 square inches per plant, respectively. The linear function of plant density was highly significant. The late maturity group was significantly highest, while the early maturity group was significantly lowest in nitrogen percentage. Nitrogen percentages of 2.01, 1.91, and 1.83 were found for late, early, and medium maturities, respectively.

Powhattan 1965. Appendix Table 58 shows no difference in nitrogen percentage by varying plant density. Nitrogen percentage was 2.06 and highest

with RS 608. All other hybrids were not significantly different. The early maturity group was significantly higher in nitrogen content than the medium and late maturities, which did not differ. Percentage values of 1.96, 1.89, and 1.87 were found for early, medium, and late maturity groups, respectively.

Hutchinson 1964. There were no differences in nitrogen percentages with the three lowest populations, as shown in Appendix Table 59. The least plant area resulted in the lowest nitrogen content of the grain. Nitrogen level decreased from 2.22 to 2.01% with 320 and 80 square inches per plant, respectively. Both linear and quadratic functions of plant density were highly significant. No hybrid was significantly highest or lowest in nitrogen content. Nitrogen percentage varied from 2.22 to 2.08 for RS 608 and KS 652, respectively. There were no differences in nitrogen content among maturity groups.

Hutchinson 1965. Data in Appendix Table 60 show that the two lowest populations were significantly higher in nitrogen content than the two highest populations. By decreasing area per plant from 440 to 320 square inches, nitrogen content decreased from 1.94 to 1.84%. Only the linear function of plant density was highly significant. RS 608, with 1.97%, was significantly highest in nitrogen content and RS 610, with 1.79%, was significantly lowest. Hybrids within maturities were highly significant due to the difference in the means of the early maturity group. There were no differences in maturity groups.

#### SUMMARY AND CONCLUSIONS

A study was conducted at Manhattan and Hutchinson in 1964 and 1965 and at Powhattan in 1965 to determine maturity and plant density effects on grain yield, yield components, nitrogen accumulation in the plant and incorporation

in the grain. Two hybrids each of early, medium, and late maturity were represented and established in stand densities of 80, 200, 320, and 440 square inches per plant.

Grain yields and components were determined for both years and nitrogen yields per plant were determined at half-bloom and at physiologic maturity in 1965. Nitrogen determinations were made for the grain and vegetative portions of the plant at physiologic maturity.

In both years grain yields per acre increased consistently and linearly by decreasing area per plant from 440 to 80 square inches at two locations which received average or above average rainfall. At another location under drought conditions grain yields were not affected by varying plant density in 1964, but the three highest densities produced equal and superior yields to the lowest density in 1965. A greater amount of tillering with the lowest populations with limiting moisture compared to adequate moisture conditions resulted in less difference among plant densities on heads per unit area.

Generally, increased number of seeds per head and increased tillering failed to compensate for the large number of heads that developed with the highest population under favorable conditions. Seeds per head and heads per unit area were much more variable than grain yield, but the two components tended to vary in opposite directions. Seed weight was the component varying the least. With each later maturity group there was, in general, an increase in number of seeds per head and seed weight, but a decrease in number of heads per unit area due to decreased tillering. Grain yields were more consistently the highest with late maturity hybrids under all conditions. Less difference was noted in grain yields between early and medium hybrids than between medium and late hybrids. Early maturity hybrids were lowest in grain

yield in most cases, although RS 610 nearly always outyielded RS 608, the other early maturity hybrid, and frequently outyielded the two medium maturity hybrids.

Accumulation of dry matter per plant at half-bloom was highest with late maturity hybrids at all three locations in 1965. Except at Powhattan, early maturing hybrids were lowest in dry matter production. There was much more variations among maturities than with hybrids within maturities. The lowest population yielded the largest amount of dry matter per plant at two of three locations and the highest population yielded the least dry matter per plant at all three locations.

In general, late maturity hybrids produced greater yields of nitrogen per plant at half-bloom and at physiologic maturity. Greatest amounts of nitrogen per plant at half-bloom were found with late maturing hybrids except at 80 square inches per plant at Powhattan in 1965. Medium maturity hybrids were higher than the early maturity hybrids only at Hutchinson.

Increased accumulation of nitrogen per plant was obtained from increasing area per plant. In most instances highest nitrogen yields corresponded to highest dry matter yields at half-bloom.

Total nitrogen per plant at maturity varied, due to differences in uptake of nitrogen from half-bloom to physiologic maturity. At Manhattan and Powhattan in 1965, under favorable moisture and fertility conditions, total nitrogen in the plant at maturity was highest with late maturity hybrids. This was associated with a greater uptake of nitrogen with the late maturity hybrids at Manhattan, but with no maturity differences at Powhattan. At Hutchinson, where moisture was limiting both years, there were no differences among maturities in total nitrogen in the plant at maturity. This was the

result of a decreased amount of nitrogen uptake by the late maturity hybrids from half-bloom to physiologic maturity. Total amount of nitrogen per plant at maturity increased with increased area per plant.

Total nitrogen per plant in the grain portion at maturity was highest for late maturity hybrids and lowest for medium maturity hybrids at Manhattan and Powhattan in 1965. Increasing area per plant increased nitrogen per plant in the grain portion at maturity. There were no hybrid or maturity differences in grain nitrogen at Hutchinson in 1965. The trends were very closely related to the amounts of nitrogen in the whole plant at maturity.

Based on these results, it was concluded that:

- 1) the highest population (80 square inches per plant) was superior to all others tested under favorable moisture and fertility conditions,
- 2) the lowest population (440 square inches per plant) was inferior, even under drought conditions,
- 3) late maturity hybrids accumulated more nitrogen and dry matter per plant at half-bloom than early and medium maturity hybrids,
- 4) late maturity hybrids took up more nitrogen, even after half-bloom, than early and maturity hybrids, if adequate moisture and fertility existed,
- 5) nitrogen uptake after half-bloom may have markedly influenced nitrogen content of the grain and,
- 6) nitrogen percentage in the grain did not follow a trend with maturities, but in most cases increased with decreased stand density and decreased yield.

## ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. F. C Stickler for assistance in planning the experiment.

Appreciation is expressed to Dr. R. L. Vanderlip for his help and guidance in conducting the study and preparing the manuscript.

#### LITERATURE CITED

1. Abbe, E. E., L. F. Randolph, and J. Einset. 1941. The developmental relationship between shoot apex and growth pattern of leaf blade in diploid maize. *Am. J. Bot.* 28: 778-784.
2. Association of Official Agricultural Chemists. 1940. *Official Methods of Analysis*. Washington, D.C. Ed. 5.
3. Association of Official Agricultural Chemists. 1955. *Official Methods of Analysis*. Washington, D.C. Ed. 8.
4. Bond, J. J., T. J. Army, and O. R. Lehman. 1964. Row spacing, plant populations, and moisture supply as factors in dryland grain sorghum production. *Agron. J.* 56:3-6.
5. Brown, P. J., and W. D. Shrader. 1959. Grain yields, evapotranspiration, and water use efficiency of grain sorghum under different cultural practices. *Agron. J.* 51: 339-343.
6. Burnside, O. C., C. R. Fenster, and G. A. Wicks. 1964. Influence of tillage, row spacing, and atrazine on yield components of dryland sorghum in Nebraska. *Agron. J.* 56: 397-400.
7. Doty, W. M., M. S. Bergdoll, and S. R. Miles. 1943. The chemical composition of commercial hybrids and open-pollinated varieties of dent corn and their relation to soil, season, and degree of maturity. *Cereal Chem.* 20: 113-120.
8. \_\_\_\_\_, H. A. Nash, and A. M. Brunson. 1946. Amino acids in corn grain of several single crosses. *Cereal Chem.* 23: 199-210.
9. Fraps, G. S. 1931. Variations in vitamin A and chemical composition of corn. *Tex. Agr. Exp. Sta. Bul.* 422.
10. Frey, K. J. 1949. The inheritance of protein and certain of its components in maize. *Agron. J.* 41: 113-117.
11. Greaves, J. E., and D. H. Nelson. 1925. The influence of irrigation water and manure on the composition of the corn kernel. *J. Agr. Res.* 31: 183-189.
12. Grimes, D. W., and J. T. Musick. 1959. How plant spacing, fertility, and irrigation affect grain sorghum production in Southwestern Kansas. *Kans. Agr. Exp. Sta. Bul.* 414.
13. Hanway, J. J. 1962. Corn growth and composition in relation to soil fertility: II. Uptake of N, P, and K, and their distribution in different plant parts during the growing season. *Agron. J.* 54: 217-222.

14. Herron, G. M., D. W. Grimes, and J. T. Musick. 1963. Effects of soil moisture and nitrogen fertilization of irrigated grain sorghum on dry matter production and nitrogen uptake at selected stages of plant development. *Agron. J.* 55: 393-396.
15. Illinois Agr. Exp. Sta., 1st annual report. 1942. High-low chemical strains well established in white corn. pp. 47-48.
16. Karper, R. E., and J. R. Quinby. 1937. Hybrid vigor in sorghum. *J. Hered.* 28: 83-91.
17. \_\_\_\_\_ 1947. Sorghum -- its production, utilization and breeding. *Econ. Bot.* 1(4): 355-371.
18. \_\_\_\_\_, D. L. Jones, and R. E. Dickson. 1931. Grain sorghum date of planting and spacing experiments. *Tex. Agr. Exp. Sta. Bul.* 424.
19. Kiesselbach, T. A., A. Anderson, and W. E. Lyness. 1935. Cultural practices in corn production. *Neb. Agr. Exp. Sta. Bul.* 293.
20. Laude, H. H., and A. F. Swanson. 1933. Sorghum production in Kansas. *Kans. Agr. Exp. Sta. Bul.* 265.
21. LeClerg, E., W. Leonard, and A. Clark. 1962. *Field Plot Technique.* Burgess Publishing Company. Ed. 2.
22. Leonard, W. H., and J. H. Martin. 1963. *Cereal Crops.* The Macmillan Company. New York.
23. Miller, G. D., C. W. Deyoe, T. L. Walter, and F. W. Smith. 1964. Variations in protein levels in Kansas sorghum grain. *Agron. J.* 56: 302-304.
24. Morrison, F. B. 1948. *Feeds and Feeding.* 20th Ed. The Morrison Publishing Co. Ithaca, N. Y. p.1120.
25. Nelson, C. E. 1952. Effects of spacing and nitrogen applications on yield of grain sorghum under irrigation. *Agron. J.* 44: 303-305.
26. Painter, C. G., and R. W. Leamer. 1953. The effects of moisture, spacing, fertility, and their interrelationship on grain sorghum production. *Agron. J.* 45: 261-268.
27. Porter, K. B., M. E. Jensen, W. H. Sletten. 1960. The effect of row spacing, fertilizer, and planting rate on the yield and water use of irrigated grain sorghum. *Agron. J.* 52: 431-434.
28. Quinby, J. R. 1965. The fourth maturity gene locus in sorghum. *Agronomy Abstracts, 1965 Annual Meetings Amer. Soc. Agron.*
29. \_\_\_\_\_, and R. E. Karper. 1945. The inheritance of three genes that influence time of floral initiation and maturity date in milo. *J. Am. Soc. Agron.* 37(11): 916-936.



## APPENDIX

## Yield Data - Manhattan - 1964

Table 1. Grain yield per acre.

Source	d.f.	Ss	Ms	F
Replications	3	39,801,800	13,267,266	35.73 **
Densities	3	66,785,700	22,261,900	59.96 **
Linear	(1)		64,421,181	173.50 **
Quadratic	(1)		1,078,020	2.90
Residual	(1)		1,286,499	3.46
Error a	9	3,341,700	371,300	
Hybrids	5	14,389,200	2,877,840	17.56 **
Hyb.: Mat.	(3)	4,484,791	1,494,930	9.12 **
Maturities	(2)	9,904,409	4,952,204	30.22 **
H x D	15	4,279,600	285,307	
Error b	60	9,832,200	163,870	1.74

Table 2. Seed weight.

Source	d.f.	Ss	Ms	F
Replications	3	19.8640	6.6213	2.03
Densities	3	95.9400	31.9800	9.79 **
Linear	(1)		83.0419	25.42 **
Quadratic	(1)		12.8700	3.94
Residual	(1)		.0281	0.01
Error a	9	29.4050	3.2672	
Hybrids	5	639.0780	127.8156	103.16 **
Hyb.: Mat.	(3)	55.3416	18.4472	14.89 **
Maturities	(2)	583.7364	291.8682	235.56 **
H x D	15	23.3010	1.5534	
Error b	60	74.3460	1.2391	1.25

\*\* Significant at the 1% level.

Table 3. Number of seeds per head.

Source	d.f.	Ss	Ms	F
Replications	3	4,943,630	1,647,877	8.33 **
Densities	3	38,533,440	12,844,480	64.95 **
Linear	(1)		32,344,602	163.57 **
Quadratic	(1)		4,262,630	21.56 **
Residual	(1)		1,926,209	9.74 **
Error a	9	1,779,710	197,746	
Hybrids	5	1,223,480	244,696	2.30
Hyb.: Mat.	(3)	-	-	-
Maturities	(2)	-	-	-
H x D	15	673,230	44,882	0.42
Error b	60	6,375,000	106,250	

Table 4. Heads per plot.

Source	d.f.	Ss	Ms	F
Replications	3	962.0200	320.6733	5.61 *
Densities	3	290,612.0200	66,870.6730	1,170.60 **
Linear	(1)		160,417.9600	2,808.10 **
Quadratic	(1)		35,844.0100	627.40 **
Residual	(1)		4,350.0500	76.10 **
Error a	9	514.1400	57.1267	
Hybrids	5	325.6700	65.1340	1.41
Hyb.: Mat.	(3)	-	-	-
Maturities	(2)	-	-	-
H x D	15	534.3000	35.6200	0.77
Error b	60	2,766.5880	46.1098	

\* Significant at the 5% level.

\*\* Significant at the 1% level.

## Yield Data - Manhattan - 1965

Table 5. Grain yield per acre.

Source	d.f.	Ss	Ms	F
Replications	3	2,270,800	756,933	2.16
Densities	3	20,350,500	6,783,500	19.35 **
Linear	(1)		19,871,368	56.69 **
Quadratic	(1)		38,400	0.11
Residual	(1)		4,407	1.26
Error a	9	3,154,800	350,533	
Hybrids	5	10,678,000	2,135,600	20.09 **
Hyb.: Mat	(3)	4,300,430	1,433,477	13.49 **
Maturities	(2)	6,377,570	3,188,785	30.00 **
H x D	15	3,207,600	213,840	2.01 *
Error b	60	6,376,600	106,277	

Table 6. Seed weight.

Source	d.f.	Ss	Ms	F
Replications	3	20.4550	6.8183	1.91
Densities	3	69.0690	23.0230	6.44 *
Linear	(1)		44.9086	12.57 **
Quadratic	(1)		22.8345	6.39 *
Residual	(1)		132.5930	0.37
Error a	9	32.1540	3.5727	
Hybrids	5	69.6710	13.9342	24.63 **
Hyb.: Mat	(3)	55.5664	18.5221	32.74 **
Maturities	(2)	14.1046	7.0523	12.46 **
H x D	15	19.0960	1.2731	2.25 *
Error b	60	33.9490	.5658	

\* Significant at the 5% level.

\*\* Significant at the 1% level.

Table 7. Number of seeds per head.

Source	d.f.	Ss	Ms	F
Replications	3	2,975,770	991,923	4.38 *
Densities	3	41,657,380	13,885,793	61.36 **
Linear	(1)		32,041,600	141.58 **
Quadratic	(1)		7,982,220	35.27 **
Residual	(1)		1,633,560	6.91 *
Error a	9	2,036,760	226,307	
Hybrids	5	6,378,730	1,275,746	45.54 **
Hyb.: Mat	(3)	576,784	192,261	6.86 **
Maturities	(2)	5,801,946	2,900,973	103.55 **
H x D	15	1,853,800	123,587	
Error b	60	1,680,900	28,015	4.41 **

Table 8. Heads per plot.

Source	d.f.	Ss	Ms	F
Replications	3	5,498.51	1,832.84	5.31 *
Densities	3	155,971.10	51,990.37	150.65 **
Linear	(1)		111,112.10	321.96 **
Quadratic	(1)		37,643.76	109.08 **
Residual	(1)		7,215.24	20.91 **
Error a	9	3,105.98	345.11	
Hybrids	5	1,753.55	350.71	7.25 **
Hyb.: Mat	(3)	23.73	7.91	0.16
Maturities	(2)	1,729.82	864.91	17.87 **
H x D	15	1,909.49	127.30	
Error b	60	2,901.37	48.36	2.63 **

\* Significant at the 5% level.

\*\* Significant at the 1% level.

## Yield Data - Powhatan - 1965

Table 9. Grain yield per acre.

Source	d.f.	Ss	Ms	F
Replications	3	3,337,300	1,112,433	1.03
Densities	3	16,331,600	5,443,867	5.04 *
Linear	(1)		10,805,700	10.01 *
Quadratic	(1)		5,270,157	4.88
Residual	(1)		255,743	0.24
Error a	9	9,717,700	1,079,744	
Hybrids	5	8,661,300	1,732,260	10.64 **
Hyb.: Mat	(3)	7,173,544	2,391,181	14.69 **
Maturities	(2)	1,487,756	743,878	4.57 *
H x D	15	350,093	350,093	
Error b	60	9,765,960	162,767	2.15 *

Table 10. Seed weight.

Source	d.f.	Ss	Ms	F
Replications	3	2.8270	.9423	0.59
Densities	3	147.0920	49.0307	30.61 **
Linear	(1)		130.8236	81.67 **
Quadratic	(1)		12.4056	7.74 *
Residual	(1)		3.8627	2.41
Error a	9	14.4160	1.6018	
Hybrids	5	238.6030	47.7206	41.56 **
Hyb.: Mat.	(3)	150.1648	50.0549	43.59 **
Maturities	(2)	88.4382	44.2191	38.51 **
H x D	15	54.7720	3.6515	
Error b	60	68.8950	1.1483	3.18 **

\* Significant at the 5% level.

\*\* Significant at the 1% level.

Table 11. Number of seeds per head.

Source	d.f.	Ss	Ms	F
Replications	3	604,380	201,460	0.69
Densities	3	31,903,140	10,634,380	36.19 **
Linear	(1)		28,687,185	97.62 **
Quadratic	(1)		29,368,508	99.90 **
Residual	(1)		279,104	0.95
Error a	9	2,644,780	293,864	
Hybrids	5	10,009,370	2,001,874	37.44 **
Hyb.: Mat	(3)	1,449,589	483,196	9.04 **
Maturities	(2)	8,559,781	4,279,890	80.04 **
H x D	15	6,212,490	414,166	7.75 **
Error b	60	3,208,500	53,475	

Table 12. Heads per plot.

Source	d.f.	Ss	Ms	F
Replications	3	1,182.20	394.07	0.78
Densities	3	32,827.27	32,827.27	64.56 **
Linear	(1)		91,881.00	180.71 **
Quadratic	(1)		6,288.84	12.37 **
Residual	(1)		311.95	0.61
Error a	9	4,576.00	508.44	
Hybrids	5	10,613.30	2,122.66	27.05 **
Hyb.: Mat	(3)	479.76	159.92	2.04
Maturities	(2)	10,133.54	5,066.77	64.57 **
H x D	15	10,062.90	670.86	8.55 **
Error b	60	4,707.90	78.47	

\*\* Significant at the 1% level.

## Yield Data - Hutchinson 1964

Table 13. Grain yield per acre.

Source	d.f.	Ss	Ms	F
Replications	3	883,220	294,407	0.97
Densities	3	74,980	24,993	0.08
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	2,727,230	303,026	
Hybrids	5	6,602,240	1,320,448	7.45 **
Hyb.: Mat	(3)	5,285,560	1,761,853	9.94 **
Maturities	(2)	1,316,679	658,340	3.71 *
H x D	15	5,430,050	362,003	2.04 *
Error b	60	10,633,930	177,232	

Table 14. Seed weight.

Source	d.f.	Ss	Ms	F
Replications	3	2.2910	.7637	0.23
Densities	3	293.5950	.97.8650	29.64 **
Linear	(1)		211.3778	64.03 **
Quadratic	(1)		72.6102	21.99 **
Residual	(1)		9.6070	2.91
Error a	9	29.7120	3.3013	
Hybrids	5	29.3650	5.8730	4.11 **
Hyb.: Mat	(3)	28.2248	9.4083	6.59 **
Maturities	(2)	1.1402	.5701	0.40
H x D	15	38.2420	2.5495	1.78
Error b	60	85.6998	1.4283	

\* Significant at the 5% level.

\*\* Significant at the 1% level.

Table 15. Seeds per head.

Source	d.f.	Ss	Ms	F
Replications	3	380,450	126,817	1.82
Densities	3	10,897,370	3,632,457	52.04 **
Linear	(1)		9,233,536	132.28 **
Quadratic	(1)		1,542,294	22.10 **
Residual	(1)		1,215	1.74
Error a	9	628,220	69,802	
Hybrids	5	2,397,700	479,540	9.27 **
Hyb.: Mat	(3)	1,312,654	437,551	8.46 **
Maturities	(2)	1,085,046	542,523	10.49 **
H x D	15	2,329,820	155,321	3.00 **
Error b	60	3,102,846	51,714	

Table 16. Heads per plot.

Source	d.f.	Ss	Ms	F
Replications	3	2,542.20	847.40	1.08
Densities	3	269,794.90	89,931.63	114.48 **
Linear	(1)		195,697.63	249.10 **
Quadratic	(1)		65,730.67	83.67 **
Residual	(1)		8,366.60	10.65 **
Error a	9	7,070.40	785.60	
Hybrids	5	6,488.20	1,297.64	7.22 **
Hyb.: Mat.	(3)	1,904.00	634.67	3.53 *
Maturities	(2)	4,584.20	2,292.10	12.75 **
H x D	15	19,271.00	1,284.73	7.15 **
Error b	60	10,787.90	179.80	

\* Significant at the 5% level.

\*\* Significant at the 1% level.

## Yield Data - Hutchinson - 1965

Table 17. Grain yield per acre.

Source	d.f.	Ss	Ms	F
Replications	3	832,600	277,533	3.62
Densities	3	3,252,400	1,084,133	14.15 **
Linear	(1)		932,363	12.17 **
Quadratic	(1)		2,006,528	26.17 **
Residual	(1)		3,134	4.09
Error a	9	689,500	76,611	
Hybrids	5	7,251,000	1,450,200	27.10 **
Hyb.: Mat	(3)	2,966,868	988,956	18.48 **
Maturities	(2)	4,284,132	2,142,066	40.02 **
H x D	15	1,507,500	100,500	1.78
Error b	60	3,211,296	53,521	

Table 18. Seed weight.

Source	d.f.	Ss	Ms	F
Replications	3	10.5560	3.5187	2.55
Densities	3	110.7750	36.9250	26.73 **
Linear	(1)		69.1070	50.02 **
Quadratic	(1)		36.2481	26.24 **
Residual	(1)		5.4199	3.92
Error a	9	12.4340	1.3816	
Hybrids	5	374.3230	74.8646	28.40 **
Hyb.: Mat	(3)	57.6152	19.2051	7.29 **
Maturities	(2)	316.7078	158.3539	60.07 **
H x D	15	66.0600	4.4040	1.67
Error b	60	158.1600	2.6360	

\*\* Significant at the 1% level.

Table 19. Seeds per head.

Source	d.f.	Ss	Ms	F
Replications	3	373,030	124,343	1.84
Densities	3	69,090,400	23,030,133	341.16 **
Linear	(1)		62,895,327	931.71 **
Quadratic	(1)		6,194,552	91.76 **
Residual	(1)		521	0.07
Error a	9	607,550	67,506	
Hybrids	5	1,046,200	209,240	2.34
Hyb.: Mat	(3)	-	-	-
Maturities	(2)	-	-	-
H x D	15	2,217,470	147,831	1.65
Error b	60	5,364,760	89,413	

Table 20. Heads per plot.

Source	d.f.	Ss	Ms	F
Replications	3	145.50	48.50	2.07
Densities	3	202,502.24	67,500.75	2,878.90 **
Linear	(1)		159,359.40	6,796.70 **
Quadratic	(1)		39,772.04	1,696.30 **
Residual	(1)		33.71	143.80 **
Error a	9	211.02	23.45	
Hybrids	5	370.20	74.04	3.66 **
Hyb.: Mat.	(3)	89.20	29.73	1.47
Maturities	(2)	281.00	140.50	7.00 **
H x D	15	541.40	36.09	1.78
Error b	60	1,213.48	20.22	

\*\* Significant at the 1% level.

Table 21. Significant correlations for 96 observation comparisons -  
( $r = .20$ , 5% level).

	Manhattan		Powhatan		Hutchinson
	1964	1965	1965	1964	1965
Grain yield & seed wt			-.31	.23	.39
" " & seeds per head	-.30	-.48			.43
" " & heads per unit area	.66	.66	.42		
" " & % N in grain	-.71	-.30	-.29	-.40	-.41
Seed wt & seeds per head			.57	-.51	.51
" " & heads per unit area	-.36	-.62	.40	-.72	-.38
" " & % N in grain	.31	.27	-.43	.48	.19
Seeds per hd & heads per unit area	-.84	-.93	-.90	-.85	-.93
" " " & % N in grain			.50		.23
" " " " " " "	-.41	-.46		-.33	-.27
Seed wt & veg. yield. (half-bloom)	*	.55		*	.65
" " & total N grain					.22
" " & uptake			-.31	.29	-.44
Seeds per hd and veg yield (half-bloom)			.87	.79	.62
" " " " total N veg (half-bloom)			.88	.85	.69
" " " " total N veg - Mat.			.86	.75	.84
" " " " total N grain			.31		.30
" " " " uptake			-.60	-.67	-.43
Veg yield (half-bloom) total N veg (half-bloom)			.49		.45
" " total N veg - Mat.			.55		
" " total N grain			.97	.95	.98
" " uptake			.82	.70	.62
% N grain & % N veg - H.B.			.59		
" " " " total N veg - Mat.			.61		.33
" " " " grain			.26		
" " " " uptake			-.37		
Total N veg - Mat. & total N grain			.32		.35
" " " " uptake			-.59	-.56	-.37
Total N grain and uptake			.43	.44	.37

\* These and succeeding comparisons were not made at Manhattan or Hutchinson in 1964.

Table 22. Hybrid x plant density interaction on grain yield at Manhattan in 1965.

Den- sity	Hybrid					Coop T-700
	RS 610	RS 608	KS 652	RS 650	KS 701	
80	7,177 ab *	6,142 efgh	6,283 def	6,273 def	7,362 a	6,872 bc
200	6,120 efgh	5,728 ghij	6,131 efgh	5,783 fghij	6,229 defg	6,708 bcd
320	6,066 fgh	5,456 ijk	5,499 ijk	5,750 fghij	5,957 fghi	6,621 cde
440	5,652 hij	5,053 k	5,314 jk	5,129 k	5,336 jk	5,935 fghi

\* Values followed by same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

Table 23. Hybrid x plant density interaction on seed weight at Manhattan in 1965.

Den- sity	Hybrid					Coop T-700
	RS 610	RS 608	KS 652	RS 650	KS 701	
80	24.06 ghi	22.37 j	23.03 ij	24.19 gh	26.27 bc	23.13 hij
200	26.21 bcd	25.55 cdef	26.02 cde	24.99 defg	26.68 ab	24.38 fg
320	25.81 cde	24.45 fg	25.81 cde	25.84 cde	27.69 a	26.01 cde
440	25.76 cde	24.87 efg	25.77 cde	25.94 cde	27.35 ab	24.99 defg

Table 24. Hybrid x density interaction on number of seeds per head at Manhattan in 1965.

Den- sity	Hybrid					
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700
80	1,801 gh	1,702 h	1,717 h	1,654 h	1,672 h	1,995 g
200	2,976 def	2,769 ef	3,079 de	2,929 ef	3,228 d	3,521 c
320	2,965 def	2,973 def	3,171 de	2,978 def	3,648 bc	3,768 bc
440	3,161 de	3,106 de	3,157 de	3,147 de	3,891 ab	4,080 a

Table 25. Hybrid x density interaction on heads per 100 square feet at Manhattan in 1965.

Den- sity	Hybrid					
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700
80	173 a	168 a	166 ab	164 ab	175 a	156 b
200	82 cde	85 c	80 cdef	83 cd	75 cdef	82 cde
320	83 cd	79 cdef	71 efg	79 cdef	62 gh	71 efg
440	73 defg	77 cdef	72 defg	69 fg	55 h	62 gh

Table 26. Hybrid x density interaction on grain yield per acre at Powhattan in 1965.

Den- sity	Hybrid					
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700
80	6,436 bcdef	6,131 cdefg	6,262 cdefg	5,859 fg	6,371 cdef	6,785 abc
200	6,556 bcde	6,033 defg	6,131 cdefg	6,120 cdefg	6,403 cdef	7,057 ab
320	7,220 a	5,684 gh	5,968 defg	5,946 defg	5,902 efg	6,611 abcd
440	5,543 ghi	5,151 hi	5,881 efg	5,064 hi	5,016 i	5,511 ghi

Table 27. Hybrid x density interaction on seed weight at Powhattan in 1965.

Den- sity	Hybrid					
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700
80	24.59 defg	22.67 hij	24.91 def	27.18 bc	30.00 a	26.22 cd
200	23.82 fghi	22.23 ijk	23.26 fghij	25.92 cde	28.17 b	23.74 fghi
320	22.89 ghij	20.77 k	22.79 hij	23.97 fghi	24.86 def	22.37 ijk
440	23.55 fghij	21.82 jk	23.22 fghij	23.93 fghi	24.36 efgh	20.97 k

Table 28. Hybrid x density interaction on number of seeds per head at Powhatan in 1965.

Den- sity	Hybrid					
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700
80	1,618 k	1,651 jk	1,745 ijk	1,229 l	1,248 1	1,516 kl
200	2,002 ghij	2,118 efgh	2,089 fghi	1,849 hijk	2,355 defg	3,048 c
320	2,707 d	2,665 d	2,474 de	2,425 def	3,406 b	3,586 ab
440	2,623 d	2,336 defg	2,654 d	2,623 d	3,475 ab	3,808 a

Table 29. Hybrid x density interaction on heads per 100 square feet at Powhatan in 1965.

Den- sity	Hybrid					
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700
80	169.3 a	171.5 a	150.8 b	182.8 a	177.3 a	178.0 a
200	144.3 bc	134.8 cd	131.5 cd	133.3 cd	101.3 fg	102.0 fg
320	122.0 de	107.8 fg	111.0 ef	108.0 fg	74.5 j	86.8 hij
440	94.5 ghi	105.8 fg	99.8 fgh	85.0 ij	63.0 k	73.8 jk

Table 30. Hybrid x density interaction on grain yield at Hutchinson in 1964.

Den- sity	Hybrid					Coop T-700
	RS 610	RS 608	KS 652	RS 650	KS 701	
80	3,141 abc	2,562 cd	3,587 ab	2,465 cd	3,475 ab	3,653 a
200	3,082 abc	2,985 abc	3,446 ab	2,302 d	3,423 ab	3,438 ab
320	3,163 abc	3,030 abc	3,037 abc	2,908 bcd	2,978 abcd	3,379 ab
440	3,163 abc	3,156 abc	3,520 ab	3,097 abc	2,584 cd	3,386 ab

Table 31. Hybrid x density interaction on number of seeds per head at Hutchinson in 1964.

Den- sity	Hybrid					Coop T-700
	RS 610	RS 608	KS 652	RS 650	KS 701	
80	580 ij	545 j	903 ghi	482 j	921 gh	1,024 fgh
200	1,495 bcde	1,445 bcde	1,302 ef	748 hij	1,537 abcde	1,494 bcde
320	1,909 a	1,594 abcde	1,385 de	1,228 efg	1,578 abcde	1,420 cde
440	1,786 abc	1,518 bcde	1,735 abcd	1,434 bcde	1,359 def	1,808 ab

Table 32. Hybrid x density interaction on heads per 100 square feet at Hutchinson in 1964.

Den- sity	Hybrid					Coop T-70
	RS 610	RS 608	KS 652	RS 650	KS 701	
80	246.5 a	230.3 ab	195.0 c	221.5 b	167.8 d	188.8 c
200	84.8 ghijk	91.8 fghi	109.5 ef	121.8 e	87.3 fghij	96.3 fghi
320	65.0 k	75.5 hijk	97.5 fgh	89.8 fghij	74.5 ijk	99.0 fg
440	69.3 jk	80.3 ghijk	85.5 ghijk	84.0 ghijk	76.8 ghijk	77.0 ghijk

Table 33. Dry matter accumulation per plant at half-bloom at Manhattan in 1965.

Density	Maturity						Density Mean
	Early		Medium		Late		
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700	
80	43.7	41.7	53.1	45.4	50.2	53.3	47.9 c
200	66.0	66.2	75.0	65.4	86.8	84.5	74.0 b
320	71.6	76.8	84.0	77.3	93.9	89.2	82.2 a
440	75.5	78.1	87.6	74.0	103.5	97.8	86.1 a
Hybrid mean	64.2 c	65.7 c	74.9 b	65.5 c	83.6 a	81.2 a	
Maturity mean	65.0 c		70.2 b		82.4 a		

Table 34. Dry matter accumulation per plant at half-bloom at Powhattan in 1965.

Density	Maturity						Density Mean
	Early		Medium		Late		
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700	
80	48.4	43.6	52.3	45.3	55.2	61.1	51.0 d
200	55.9	54.4	58.3	58.5	83.1	84.8	65.8 c
320	59.6	62.9	63.7	61.0	92.9	92.1	72.0 b
440	61.0	66.3	70.0	66.5	93.7	97.6	75.9 a
Hybrid mean	56.2 b	56.8 b	61.1 b	57.8 b	81.2 a	83.9 a	
Maturity mean	56.5 b		59.5 b		82.6 a		

Table 35. Dry matter accumulation per plant at half-bloom at Hutchinson in 1965.

Density	Maturity						Density Mean
	Early		Medium		Late		
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700	
80	40.8	35.2	45.0	38.2	59.3	58.5	46.2 c
200	48.6	50.3	63.3	61.9	69.8	72.4	61.0 b
320	57.7	48.9	67.3	59.6	86.4	85.0	67.5 b
440	59.2	60.6	78.9	67.9	97.1	88.5	75.3 a
Hybrid mean	51.6 cd	48.7 d	63.6 b	56.9 c	78.1 a	76.1 a	
Maturity mean	50.2 c		60.2 b		77.1 a		

Manhattan - 1965

Table 36. Total nitrogen per plant at half-bloom at Manhattan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	0.8460	0.2820	0.58
Densities	3	215.3579	71.7860	148.56 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a <sup>1</sup>	9	4.3489	0.4832	
Hybrids	5	23.9418	4.7884	10.97 **
Hyb.: Mat	(3)	3.7360	1.2453	2.85 *
Maturities	(2)	20.2058	10.1029	23.14 **
H x D	15	2.9520	0.5968	
Error b <sup>2</sup>	60	26.1960	0.4366	1.37

<sup>1</sup>Used to test replications, densities, and components.<sup>2</sup>Used to test hybrids and components.

\*\*Significant at the 1% level.

\*Significant at the 5% level.

Table 37. Total nitrogen per plant at physiologic maturity at Manhattan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	0.2850	0.0950	0.06
Densities	3	629.8180	209.9393	130.70 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	14.4558	1.6062	
Hybrids	5	96.0410	19.2082	26.83 **
Hyb.: Mat.	(3)	11.0800	3.6933	5.16 **
Maturities	(2)	84.9610	42.4805	58.78 **
H x D	15	19.4460	1.2964	
Error b	60	42.9600	0.7160	1.81

\*\*Significant at the 1% level.

Table 38. Total nitrogen per plant in the vegetative parts at physiologic maturity at Manhattan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	0.4500	0.1500	0.58
Densities	3	90.9045	30.3015	116.46 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	2.3418	0.2602	
Hybrids	5	14.2760	2.8552	20.40 **
Hyb.: Mat	(3)	1.0916	0.3639	2.60
Maturities	(2)	13.1844	6.5922	47.11 **
H x D	15	2.6661	0.1777	1.27
Error b	60	8.3940	0.1399	

Table 39. Total nitrogen per plant in the grain at physiologic maturity at Manhattan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	1.0904	0.3635	0.46
Densities	3	242.7810	80.9270	101.93 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	7.1460	0.7940	
Hybrids	5	37.7634	7.5527	20.31 **
Hyb.: Mat	(3)	6.4552	2.1517	5.79 **
Maturities	(2)	31.3082	15.6541	42.11 **
H x D	15	9.3110	0.6207	1.67
Error b	60	22.3080	0.3718	

\*\*Significant at the 1% level.

Table 40. Nitrogen uptake per plant from half-bloom to physiologic maturity at Manhattan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	0.2720	0.0907	0.07
Densities	3	109.3694	36.4565	27.87 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	11.7747	1.3083	
Hybrids	5	29.0894	5.8179	5.42 **
Hyb.: Mat	(3)	2.7376	0.9125	0.85 ..
Maturities	(2)	26.3518	13.1759	12.27 **
H x D	15	13.2207	0.8814	
Error b	60	64.4220	1.0737	0.82 ..

Table 41. Measurable amount of nitrogen translocated from the plant at half-bloom to the grain at maturity at Manhattan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	1.5531	0.5177	0.89
Densities	3	27.7132	9.2377	15.80 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	5.2623	0.5847	
Hybrids	5	4.2775	0.8555	1.75
Hyb.: Mat	(3)	-	-	-
Maturities	(2)	-	-	-
H x D	15	5.4748	0.3650	
Error b	60	29.3580	0.4893	0.75

\*\*Significant at the 1% level.

## Powhattan - 1965

Table 42. Total nitrogen per plant at half-bloom at Powhattan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	1.8682	0.6227	1.92
Densities	3	102.0497	34.0166	104.92 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	2.9178	0.3242	
Hybrids	5	67.0682	13.4136	55.27 **
Hyb.: Mat.	(3)	2.6300	0.8767	.36
Maturities	(2)	64.4382	32.2191	132.76 **
H x D	15	14.5410	0.9694	3.99 **
Error b	60	14.5609	0.2427	

\*\* Significant at the 1% level.

Table 43. Total nitrogen per plant at physiologic maturity at Powhattan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	1.0627	0.3542	0.24
Densities	3	116.6302	38.8767	26.38 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	13.2645	1.4738	
Hybrids	5	42.2754	8.4551	11.06 **
Hyb.: Mat.	(3)	3.7808	1.2603	1.65
Maturities	(2)	38.4946	19.2473	25.19 **
H x D	15	16.9179	1.1279	1.48
Error b	60	45.8543	0.7642	

\*\* Significant at the 1% level.

Table 44. Total nitrogen per plant in the vegetative parts at physiologic maturity at Powhatan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	0.0186	0.0062	0.04
Densities	3	15.5587	5.1862	30.33 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	1.5392	0.1710	
Hybrids	5	11.2282	2.2456	16.48 **
Hyb.: Mat.	(3)	0.6984	0.2326	1.71
Maturities	(2)	10.5298	5.2649	38.51 **
H x D	15	3.5880	0.2392	1.76
Error b	60	8.1763	0.1363	

\*\* Significant at the 1% level.

Table 45. Total nitrogen per plant in the grain at physiologic maturity at Powhatan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	1.1313	0.3771	0.43
Densities	3	47.8259	15.9420	18.14 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	7.9111	0.8790	
Hybrids	5	12.4911	2.4982	5.97 **
Hyb.: Mat.	(3)	1.6114	0.5371	1.28
Maturities	(2)	10.8797	5.4399	13.00 **
H x D	15	6.7866	0.4524	1.08
Error b	60	25.1082	0.4185	

\*\* Significant at the 1% level.

Table 46. Nitrogen uptake per plant from half-bloom to physiologic maturity at Powhatan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	4.2273	1.4091	1.18
Densities	3	4.1991	1.3997	1.17
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	10.7582	1.1954	
Hybrids	5	5.3742	1.0748	1.53
Hyb.: Mat.	(3)	-	-	-
Maturities	(2)	-	-	-
H x D	15	15.5608	1.0374	1.47
Error b	60	42.2083	0.7035	

Table 47. Measurable amount of nitrogen translocated from the plant at half-bloom to the grain at Powhatan in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	1.8362	0.6121	2.92
Densities	3	41.6898	13.8966	66.40 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	1.8837	0.2093	
Hybrids	5	29.1436	5.8287	20.40 **
Hyb.: Mat.	(3)	2.4002	0.8001	2.80 *
Maturities	(2)	26.7434	13.3717	46.81 **
H x D	15	10.1101	0.6740	2.36 **
Error b	60	17.1411	0.2857	

\* Significant at the 5% level.

\*\* Significant at the 1% level.

## Hutchinson - 1965

Table 48. Total nitrogen per plant at half-bloom at Hutchinson in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	5.4305	1.8102	2.16
Densities	3	91.4534	30.4845	36.36 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	7.5470	0.8386	
Hybrids	5	66.6103	13.3221	33.12 **
Hyb.: Mat	(3)	1.1809	0.3936	0.10
Maturities	(2)	65.4294	32.7147	81.34 **
H x D	15	8.1048	0.5403	1.34 ..
Error b	60	24.1310	0.4022	

Table 49. Total nitrogen per plant at physiologic maturity at Hutchinson in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	1.2815	0.4272	0.03
Densities	3	494.8084	164.9361	117.16 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	12.6705	1.4078	
Hybrids	5	7.8400	1.5680	1.44
Hyb.: Mat	(3)	-	-	-
Maturities	(2)	-	-	-
H x D	15	12.0197	0.8013	0.73
Error b	60	65.4905	1.0915	

\*\*Significant at the 1% level.

Table 50. Total nitrogen per plant in the vegetative parts at physiologic maturity at Hutchinson in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	0.6216	0.2072	0.83
Densities	3	68.4749	22.8250	91.43 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	2.2469	0.2497	
Hybrids	5	2.9759	0.5952	3.51 **
Hyb.: Mat	(3)	0.0635	0.0212	0.13
Maturities	(2)	2.9124	1.4562	8.59 **
H x D	15	3.9523	0.2635	1.55
Error b	60	10.1669	0.1694	

Table 51. Total nitrogen per plant in the grain at physiologic maturity at Hutchinson in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	0.3720	0.1240	0.20
Densities	3	195.9486	65.3162	107.47 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	5.4700	0.6078	
Hybrids	5	3.7961	0.7592	1.55
Hyb.: Mat	(3)	-	-	-
Maturities	(2)	-	-	-
H x D	15	5.1973	0.3465	0.71
Error b	60	29.3678	0.4895	

\*\*Significant at the 1% level.

Table 52. Nitrogen uptake per plant from half-bloom to physiologic maturity at Hutchinson in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	2.6798	0.8933	0.82
Densities	3	162.6971	54.2324	50.05 **
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	9.7521	1.0836	
Hybrids	5	50.4559	10.0912	6.95 **
Hyb.: Mat	(3)	4.8652	1.6217	1.12 ..
Maturities	(2)	45.5907	22.7954	15.71 **
H x D	15	14.0320	0.9355	0.64 ..
Error b	60	87.0615	1.4510	

Table 53. Measurable amount of nitrogen translocated from the plant at half-bloom to the grain at maturity at Hutchinson in 1965.

Source	d.f.	Ss	Ms	F
Replications	3	2.4501	0.8167	1.00
Densities	3	1.8254	0.6085	0.75
Linear	(1)	-	-	-
Quadratic	(1)	-	-	-
Residual	(1)	-	-	-
Error a	9	7.3158	0.8129	
Hybrids	5	44.0813	8.8163	15.02 **
Hyb.: Mat	(3)	1.3329	0.4443	0.08 ..
Maturities	(2)	42.7484	21.3742	36.40 **
H x D	15	7.1085	0.4739	0.81 ..
Error b	60	35.2346	0.5872	

\*\*Significant at the 1% level.

Table 54. Days to half-bloom at Manhattan in 1964.

Density (sq. in. per plant)	Maturity						Ave.
	Early		Medium		Late		
RS 610	RS 608	KS 652	RS 650	KS 701	T-700		Ave.
80	60.8*	61.5	65.5	65.0	71.3	70.0	65.7 a
200	60.8	62.5	66.0	65.5	73.0	71.0	66.5 a
320	62.8	63.5	65.0	65.3	74.3	72.0	67.2 a
440	62.3	64.5	65.0	65.5	74.3	72.3	67.3 a
Hybrid mean	61.7 e	63.0 d	65.5 c	65.3 c	73.2 a	71.3 b	
Maturity mean	62.4 c		65.4 b		72.3 a		

\* Means are averages of four replications.

Table 55. Days to half-bloom at Manhattan in 1965.

Density (sq. in. per plant)	Maturity						Ave.
	Early		Medium		Late		
RS 610	RS 608	KS 652	RS 650	KS 701	T-700		Ave.
80	68.8	69.0	69.5	68.5	72.8	77.3	70.2 a
200	69.3	69.0	69.5	69.3	74.0	73.0	70.7 a
320	69.5	71.5	71.8	70.0	74.5	74.5	72.0 a
440	71.3	69.5	73.0	70.8	76.0	75.0	72.6 a
Hybrid mean	69.7 c	69.8 c	70.9 b	69.6 c	74.3 a	73.7 a	
Maturity mean	69.8 b		70.3 b		74.0 a		

Table 56. Percent Kjeldahl nitrogen in the grain at Manhattan in 1964.

Density	Maturity						Density Mean
	Early		Medium		Late		
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700	
80	1.94	2.19	2.00	1.95	2.06	1.98	2.02 c
200	1.99	2.26	2.00	2.06	2.16	2.07	2.09 bc
320	2.06	2.38	2.10	2.12	2.23	2.20	2.18 a
440	2.03	2.30	2.15	2.11	2.23	2.20	2.17 ab
Hybrid mean	2.00 d	2.28 a	2.06 cd	2.06 cd	2.17 b	2.11 bc	
Maturity mean	2.14 a		2.06 b		2.14 a		

Table 57. Percent Kjeldahl nitrogen in the grain at Manhattan in 1965.

Density	Maturity						Density Mean
	Early		Medium		Late		
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700	
80	1.69	1.88	1.73	1.76	1.92	1.92	1.82 d
200	1.74	2.02	1.81	1.83	1.96	2.01	1.89 c
320	1.86	2.05	1.83	1.86	2.09	2.03	1.95 b
440	1.92	2.14	1.90	1.92	2.11	2.03	2.00 a
Hybrid mean	1.80 b	2.02 a	1.81 b	1.84 b	2.02 a	1.99 a	
Maturity mean	1.91 b		1.83 c		2.01 a		

Table 58. Percent Kjeldahl nitrogen in the grain at Powhattan in 1965.

Density	Maturity						Density Mean	
	Early		Medium		Late			
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700		
80	1.82	2.00	1.91	1.83	1.86	1.86	1.88 a	
200	1.92	2.05	1.83	1.90	1.88	1.87	1.91 a	
320	1.88	2.12	1.89	1.94	1.85	1.85	1.92 a	
440	1.86	2.07	1.87	1.95	1.87	1.94	1.92 a	
Hybrid mean	1.87 b	2.06 a	1.87 b	1.90 b	1.86 b	1.88 b		
Maturity mean	1.96 a		1.89 b		1.87 b			

Table 59. Percent Kjeldahl nitrogen in the grain at Hutchinson in 1964.

Density	Maturity						Density Mean	
	Early		Medium		Late			
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700		
80	2.14	2.19	1.91	2.06	1.93	1.83	2.01 b	
200	2.10	2.19	2.10	2.35	2.22	2.21	2.19 a	
320	2.08	2.28	2.23	2.20	2.30	2.25	2.22 a	
440	2.11	2.21	2.08	2.07	2.32	2.20	2.16 a	
Hybrid mean	2.11 cd	2.22 a	2.08 d	2.17 abc	2.19 ab	2.13 bcd		
Density mean	2.16 a		2.13 a		2.16 a			

Table 60. Percent Kjeldahl nitrogen in the grain at Hutchinson in 1965.

Density	Maturity						Density Mean
	Early		Medium		Late		
	RS 610	RS 608	KS 652	RS 650	KS 701	Coop T-700	
80	1.72	1.93	1.89	1.76	1.91	1.85	1.84 b
200	1.75	1.93	1.86	1.77	1.83	1.88	1.84 b
320	1.80	2.02	1.93	1.86	1.86	1.94	1.90 a
440	1.88	2.01	1.94	2.02	1.88	1.93	1.94 a
Hybrid mean	1.79 c	1.97 a	1.91 b	1.85 b	1.87 b	1.90 b	
Maturity mean	1.88 a		1.88 a		1.88 a		

YIELD, YIELD COMPONENTS, AND NITROGEN ACCUMULATION IN  
GRAIN SORGHUM AS AFFECTED BY MATURITY AND PLANT DENSITY

by

DAVID WILLIAM KOCH

B. S., Kansas State University, 1964

---

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1966

Grain sorghum has been a popular feed crop in the Great Plains. Yields have increased greatly in recent years, however, problems have arisen in maintaining high quality grain. This investigation was conducted to determine differences in grain yield, nitrogen uptake, and incorporation of nitrogen into the grain as affected by various maturities and plant densities.

Six hybrids representing three maturity groups, RS 610 and RS 608 (early), KS 652 and RS 650 (medium), and KS 701 and Coop T-700 (late) were established at plant densities of 80, 200, 320, and 440 square inches per plant at two locations in 1964 and three locations in 1965. The experiments were designed in a split-plot arrangement with stand densities as main plots and hybrids as sub-plots.

In 1965 the experiments included whole plant sampling at half-bloom and physiologic maturity. Plants were separated into vegetative and grain portions at physiologic maturity. Yield and yield components were calculated for both years. Nitrogen determinations were made on the grain both years and on the plant samples in 1965.

Under favorable moisture conditions grain yield per acre increased with decreased area per plant. With drought stress at one location grain yields were not affected by plant densities in 1964, but the three highest populations were equal and superior to the lowest population in 1965. Late maturity hybrids were more consistently high in grain yields under both favorable moisture and moisture stress conditions. There was less difference in grain yield between medium and early than between late and medium maturing hybrids.

The yield components seeds per head and heads per unit area were much more variable than grain yield, but tended to compensate for each other. Seed weight was the component varying the least, but generally increasing with increased area per plant. In general, increased lateness of maturity increased seed weight and number of seeds per head, but decreased the number of heads per

unit area due to decreased tillering.

Dry matter accumulation per plant at half-bloom was highest with late maturing hybrids at all three locations in 1965. Except at Powhattan, early maturity hybrids were lowest in dry matter production. The lowest population yielded the largest dry weight per plant at two of three locations and the highest population yielded the least dry weight per plant at all three locations.

Highest accumulations of nitrogen per plant at half-bloom were found with the late maturity group at every density except 80 square inches per plant at Powhattan in 1965. Medium maturity hybrids were higher than the early maturity hybrids only at Hutchinson. Highest yields of nitrogen per plant corresponded to highest dry matter accumulations per plant. Increasing area per plant increased amounts of nitrogen per plant at half-bloom.

At Manhattan and Powhattan in 1965, where adequate moisture was obtained, total nitrogen in the plant at physiologic maturity and in the grain portion was highest with the late maturity hybrids. This was associated with a greater uptake of nitrogen with the late maturity hybrids at Manhattan, but no difference in uptake among maturities at Powhattan. Under moisture stress at Hutchinson there were no differences among maturities in amount of nitrogen in the whole plant and grain portion at physiologic maturity. This was associated with a decreased amount of uptake by the late maturity hybrids from half-bloom to physiologic maturity. Total amount of nitrogen in the whole plant and in the grain portion at physiologic maturity increased with increased area per plant.

Nitrogen percentage in the grain failed to follow a trend with maturity groups. There were no differences with two experiments, in one case early maturities were high, and in another case late maturities were high. In

most instances, increasing area per plant from 80 to 440 square inches increased nitrogen percentage in the grain. This, in most cases, corresponded to decreases in grain yield.